Chapter 12 Waste Management Equipment

Contents:

Tables

Figures

Chapter 12 Waste Management Equipment

651.1200 Introduction and scope

The objective of chapter 12 is to explain the equipment used with agricultural waste handling. Machine, implement, device, tool, item, and component are often used instead of the word *equipment*. In this chapter, *equipment* refers to a specialty item specifically designed to push, lift, convey, agitate, or otherwise handle or process agricultural wastes. The term equipment does not include structural measures, such as flush gutters, tanks, stack pads, waste storage ponds, or waste treatment lagoons.

Detailed considerations for planning an Agricultural Waste Management System (AWMS) are in chapter 2 of the Agricultural Waste Management Field Handbook. The major equipment used in a waste management system is listed in figure 12–1.

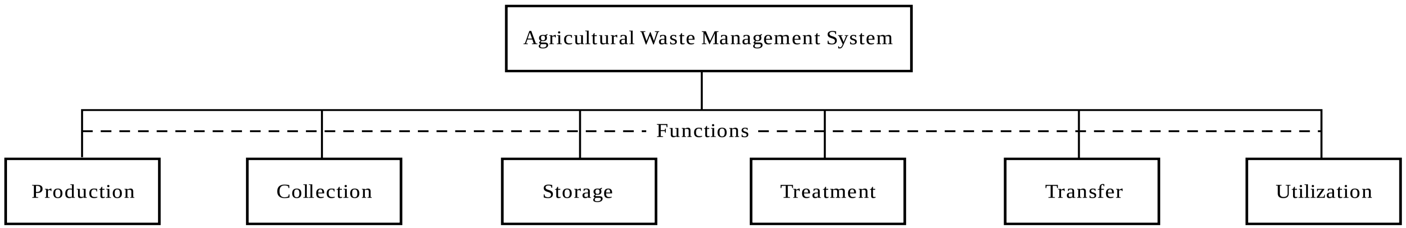
651.1201 Selecting waste handling equipment

Wastes and equipment relationships are characterized in chapters 4, 9, 10, and 11. The flowcharts in figures 12–2 to 12–5 can be used in equipment selection and handling system planning. The collection flowchart (fig. 12–3) requires that the decisionmaker know if storage is needed. This depends on climate conditions, environmental regulations, and land application space. The storage selection flowchart (fig 12–4) is based on the assumption that an earthen waste storage pond is more practical unless prevented by available space or site conditions.

In any individual situation, major considerations of equipment selection and use must meet local conditions. These considerations include climate, management, waste characteristics, available equipment sales and service, and the experience and desires of the decisionmaker. Small to medium family operations, for example, tend to use more daily labor and invest in equipment that can be multipurpose (e.g., tractor loader, elevator-conveyor, box spreader). Large operations require more, but less versatile equipment (e.g., separator, high-capacity pump, long pipeline) for separate AWMS function needs. They typically assign tasks to hired laborers to accomplish in a specified time (e.g., scraping, agitation, hauling).

Safety must be considered in addition to the cost, correct type, size, and practicality of the selected equipment. In an AWMS, relatively complex, pressurized equipment is often used by one person alone. It may be used in a noisy, remote location that is in semi-darkness and a long way from help or medical service. Suppliers, owners, and others involved must correctly instruct family and hired help about safe operation of the equipment, the hazards involved, and emergency procedures. Also, uninterrupted electric power is essential for operating some equipment (e.g., compost aerator, flushing pump, biogas production), so a system failure alarm and emergency power system may need to be a part of the AWMS.

Figure 12–1 Major equipment used in an agricultural waste management system [1/]



Production
- Roof gutters and downspouts (12-10 ff[2])
- Culvert (12-10)
- Pipe (12-10)

Collection
- Hand tools (12-13)
- Scrapers (12-1 ff)
- Loaders (12-15 ff)
- Gutter and Alley Scrapers (12-21)
- Conveyors and stackers (12-24)
- Flush gutters and alleys (12-24 ff)
- Air pressure and vacuum pumps (12-25)
- Piston-plunger pumps (12-30)

Storage
- Access ramps (12-31)
- Access ladders (12-31)
- Depth markers (12-31)
- Warnings signs (12-31)
- Valves (12-28)
- Fences (12-35)
- Covers (12-31 ff)
- See detection devices (12-38)
- Liners (12-38 ff)

Treatment
- Cutters, shredders, crushers, and grinders (12-40 ff)
- Agitators, stirrers, and mixers (12-43 ff)
- Aerators (12-48 ff)
- Separators (12-54 ff)
- Dehydrators, incinerators, and renderers (12-64 ff)

Transfer
- Augers and conveyors (12-43 ff)
- Pumps (12-35 ff)
- Picket dams (12-36 ff)

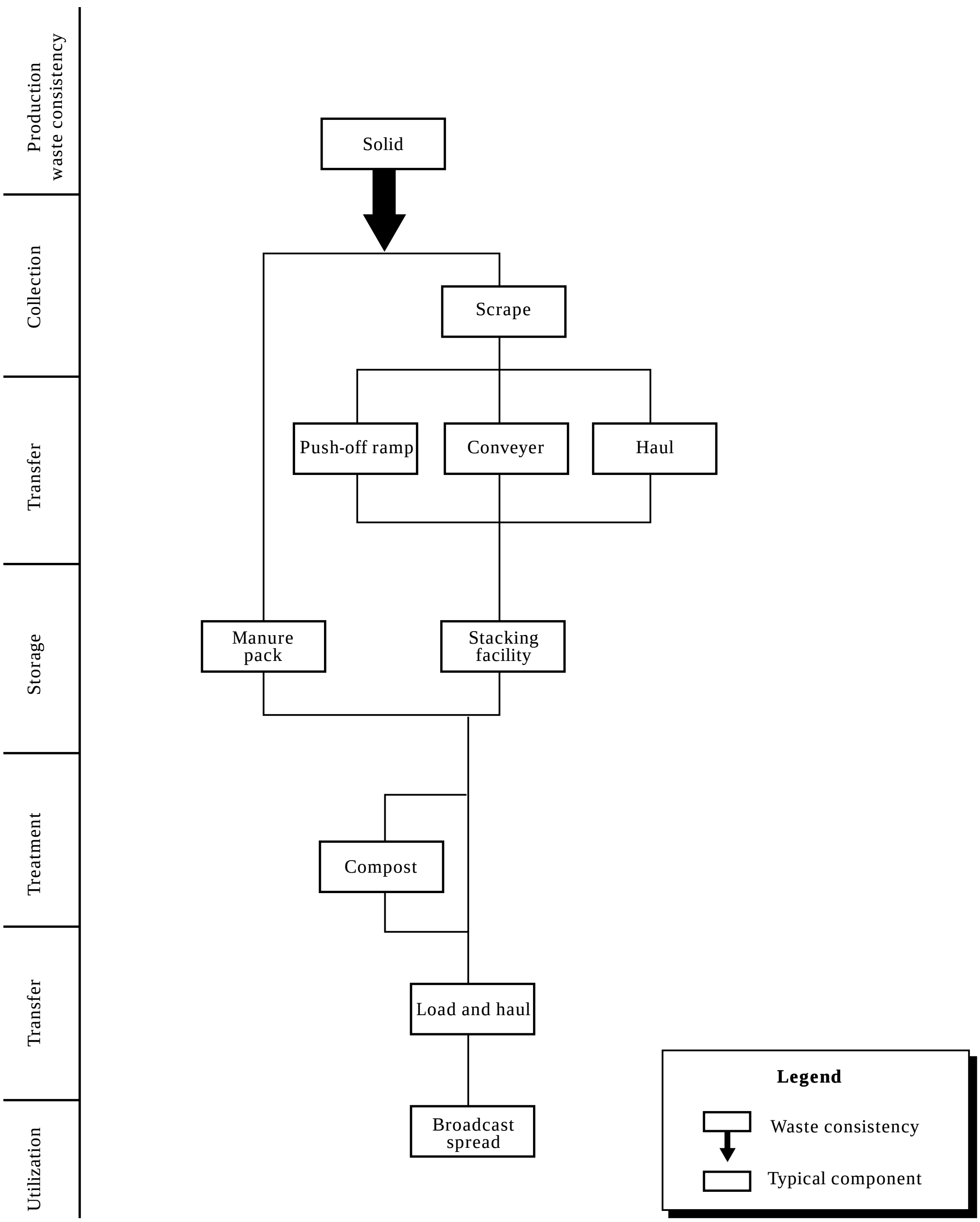
Utilization
- Box spreaders (12-73 ff)
- V-box bottom spreader (12-76 ff)
- Vacuum load tanker spreader (12-79)
- Pipe and pipelines (12-83)
- Gated pipe (12-85 ff)
- Handmove sprinkler (12-88)
- Towline sprinkler (12-89)
- Side-roll sprinkler (12-89)
- Big gun sprinkler (12-90)
- Traveling gun sprinkler (12-90 ff)
- Soil injector spreaders (12-92 ff)
- Biogas production equipment (12-94 ff)

[1] Numbers in parenthesis are the page where the equipment is described.
[2] ff—and following pages

Different models of similar equipment are available. The design and durability needed for an AWMS depends on the consistency and amount of waste and the type and length of storage. (See section 651.1000.) Some examples are:

- A tractor loader used to dig out and load packed solids should be heavier than one used for alley scraping and loadout.

Figure 12–2 Waste management typical component alternatives matrix (solid)



- A 1-horsepower pump used intermittently for liquid milkhouse waste should be designed and constructed differently than a pump that must agitate and lift swine waste that has been stored (and settled) for several months.
- A spreader for a large feedlot is designed and constructed differently than one for a 50-sow, farrow-to-finish swine operation.

Figure 12–2 Waste management typical component alternatives matrix (semi-solid/slurry)—continued

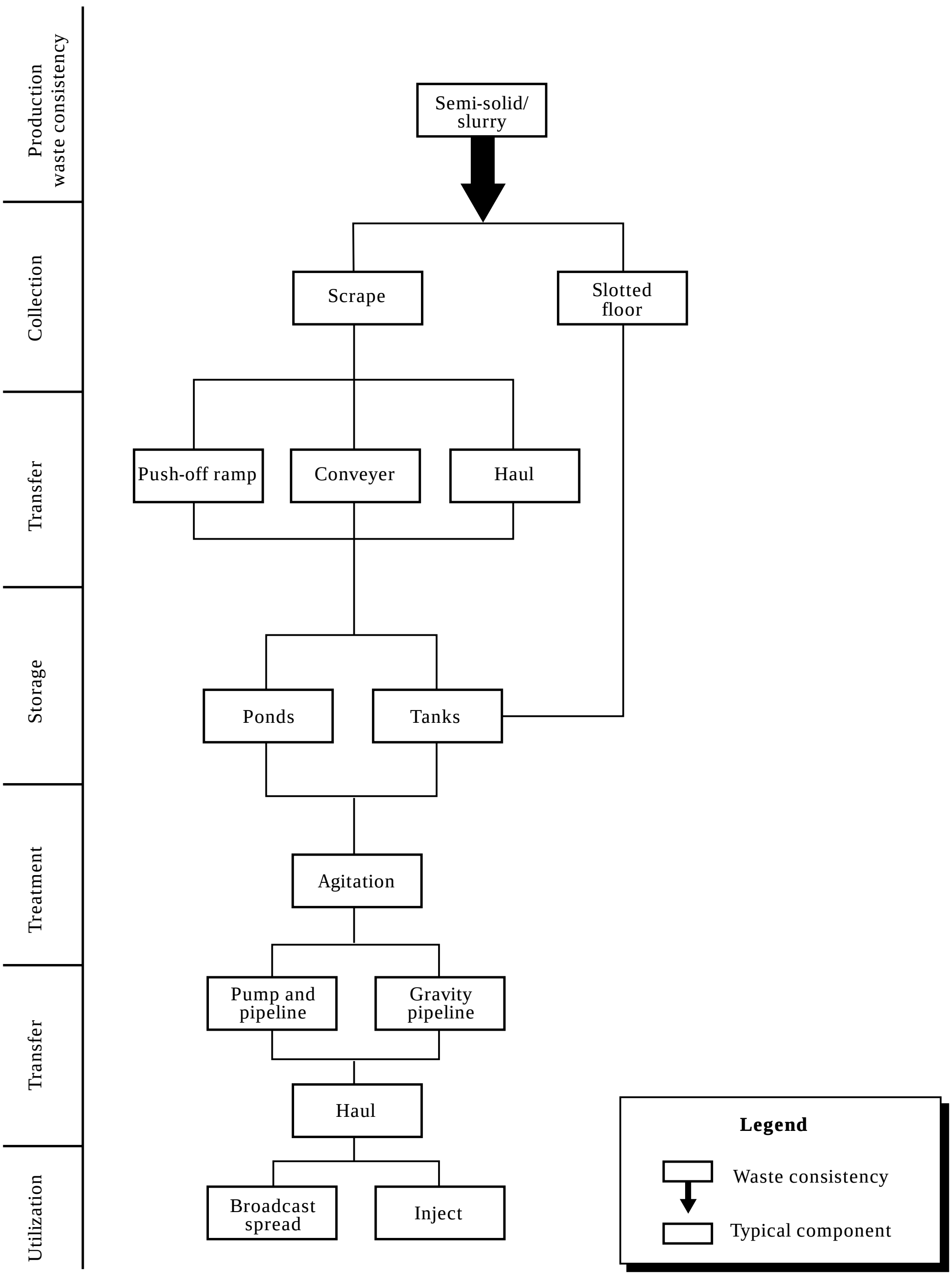


Figure 12–2 Waste management typical component alternatives matrix (liquid)—continued

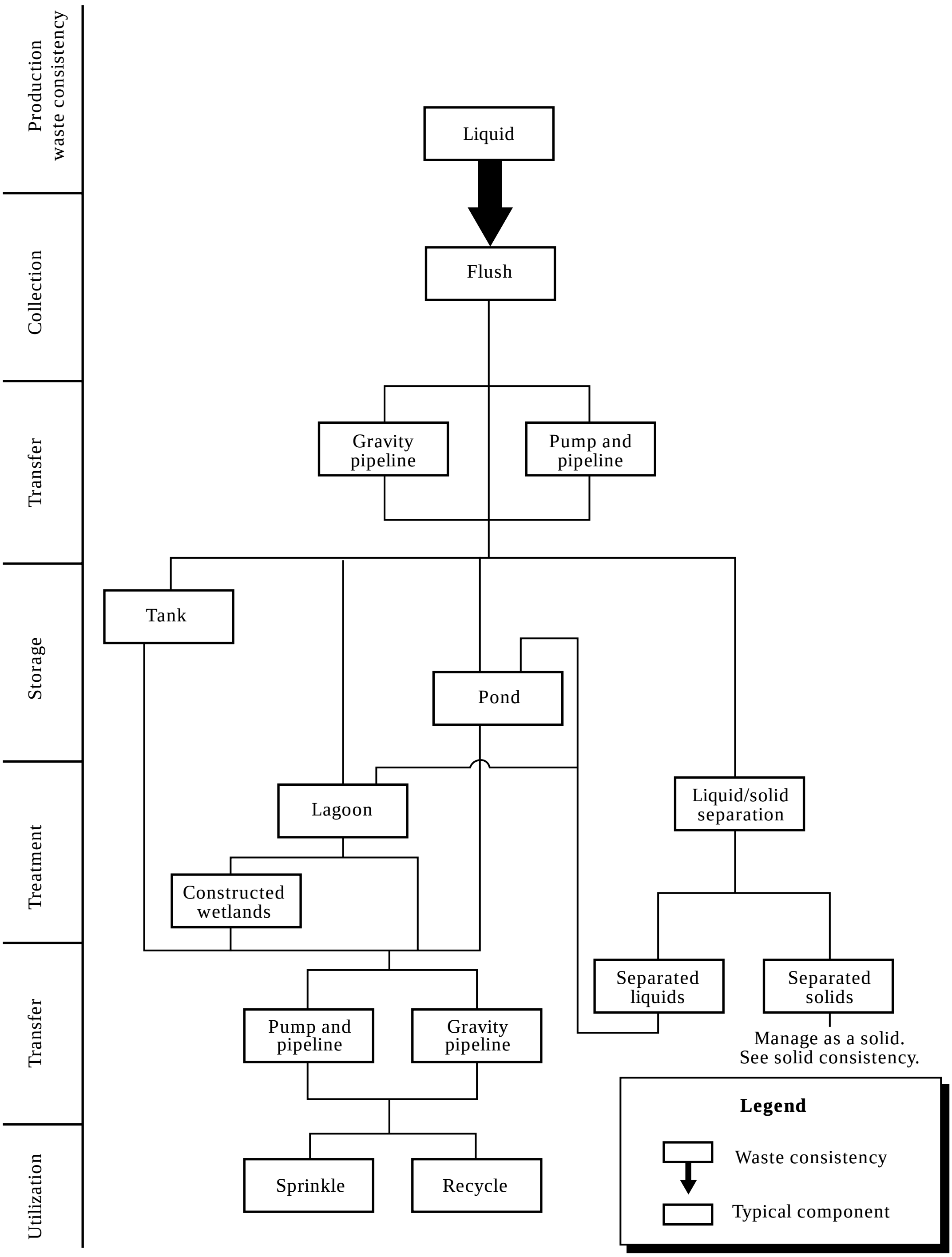


Figure 12–3 Waste management system typical collection and transfer component selection matrix

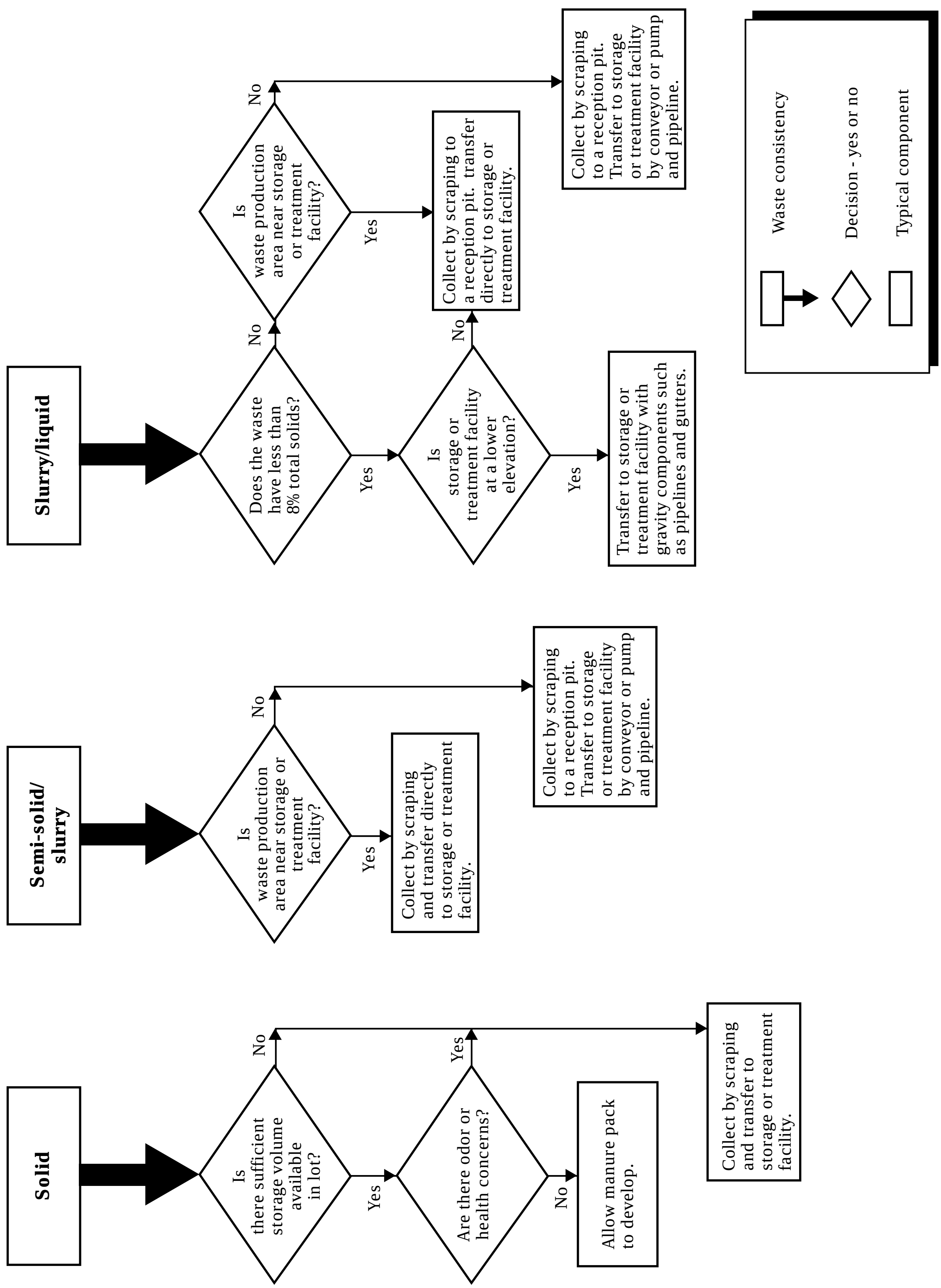


Figure 12–4 Waste management system typical storage component selection matrix

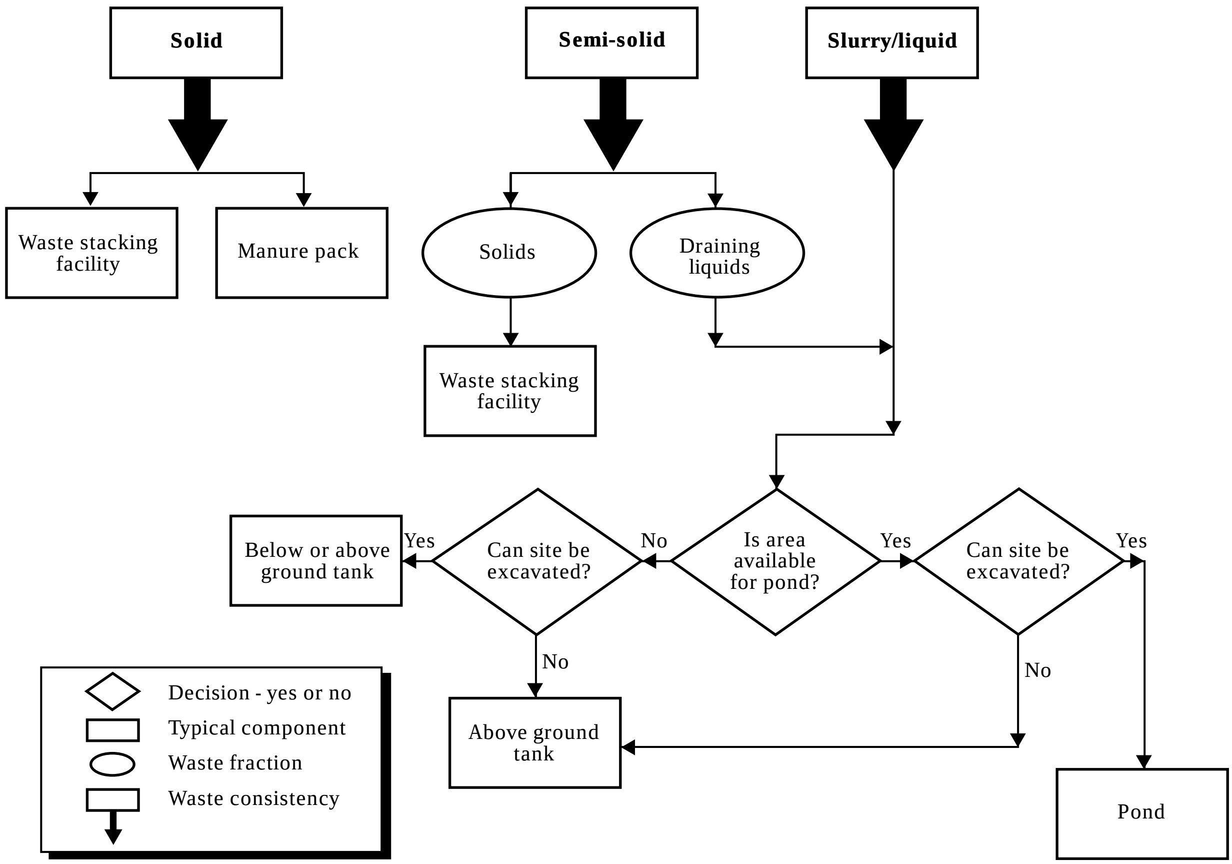
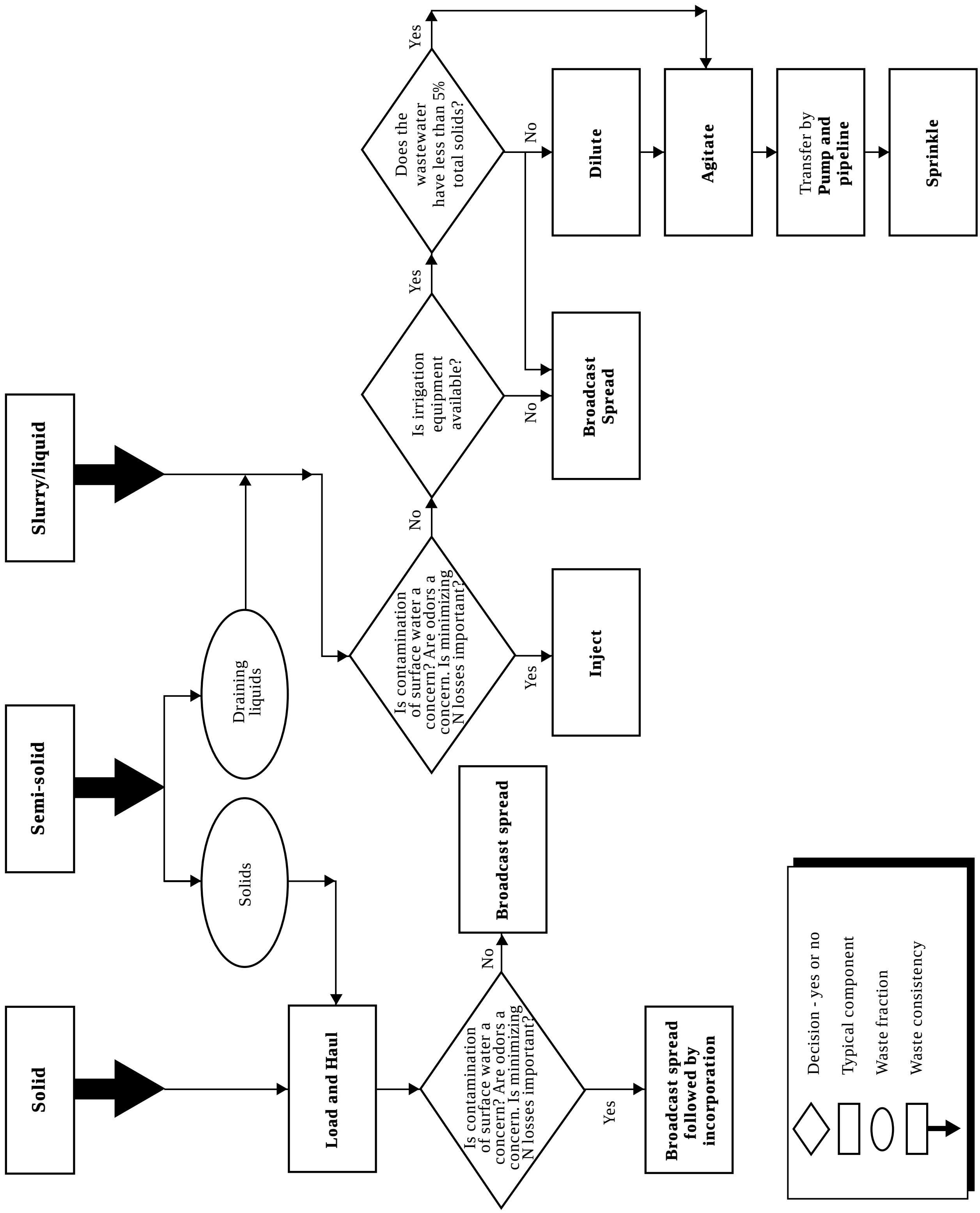


Figure 12–5 Land application typical component selection matrix



651.1202 Waste production equipment

In an agricultural waste management system, excluding clean water is considered a component of waste production (see section 651.1001). Typically this involves roof gutters, downspouts (fig. 12–6), lined or unlined ongrade waterways or open-channels (see fig. 10-1), and belowground pipes and culverts.

(a) Roof gutters (eave troughs) and downspouts

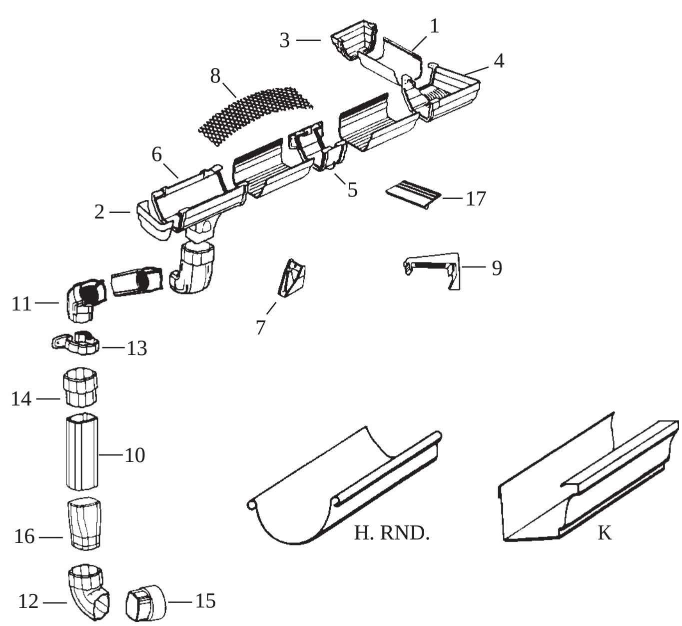
Although roof gutters require investment and maintenance, they can reduce the total quantity of waste to be handled and result in overall dollar savings for the system. NRCS Conservation Practice Standard, Roof Runoff Management, Code 558 and section 651.1001 of this handbook explain sizing of gutters and downspouts. Plastic, aluminum, and galvanized or painted steel are common gutter and downspout materials. For a given thickness, galvanized steel is the strongest and most durable. Plastic can flex with freeze-up and settling. Cast iron, steel, copper, or plastic are used for downspouts inside buildings.

Roof drainage equipment generally is supplied through building suppliers. Special fastenings may be needed to attach the equipment to a prefabricated steel building. Local independent fabricators can custom rollform light-gage metal gutter systems onsite for different buildings and do installation.

Gutter size is indicated by the top width opening. Style K box gutter is usually made in 4-, 5- and 6-inch widths; halfround gutter is made in 4-, 5-, 6-, and 7-inch diameters (fig. 12-6). A gutter is installed to slope slightly toward a downspout and is secured to the building eaves with cast iron, steel, or plastic hangars or with long spikes according to the manufacturer's specifications. Hangars need to be compatible material with the gutters and spaced accordingly. Installing the front, top edge of the gutter about 2 inches below the roof edge reduces melt water from backing up under the roofing when the gutter is frozen shut or flooded.

Figure 12–6 Roof gutter and downspout equipment (drawing courtesy of Genova Products, Inc.)

1 Gutter (10' lengths)
2 Inside end cap
3 Outside end cap
4 Gutter corner
5 Gutter slip joint
6 Highflo® drop outlet
7 Gutter bracket spacers (wedgies)
8 Debri-shield™
9 Top-notch™ gutter bracket
10 Downspout (10' lengths)
11 Front elbow - A-style
12 Side elbow - B-style
13 Downspout bracket
14 Downspout coupler
15 Downspout adapter
16 A/B downspout transition
17 Drip edge (5' lengths)
Drip edge (10' lengths)



Correct design, installation, and maintenance aid the proper operation of roof gutter and downspout drainage, especially during extreme weather. Regular cleanout of debris and dirt on screens and in gutters and downspouts is essential to prevent their plugging. Expansion and contraction from ice and temperature extremes loosen gutter and downspout supports. Snow and ice slides or buildup damage gutters and downspouts, especially lightweight types. Exterior downspouts are vulnerable to machinery and livestock damage, and some protection may be needed.

Downspouts generally are located at both ends of small buildings (<1000 ft^2 roof drainage). For large buildings, intermediate downspouts on about 30- to 50-foot spacings are installed to drain to a drainpipe or waterway sloping away from the building (see fig. 10–1 in this handbook). A float-controlled drainage sump storage and pump system is a consideration where there is insufficient slope for gravity flow.

Dripline drains are a viable option to roof gutters, especially where the designer must address freezing, snow damage, or uneven roof lines. As with downspouts, dripline drains must be protected from livestock and vehicle traffic.

Figure 12–7 Corrugated plastic drainpipe (courtesy Advanced Drainage Systems)

(b) Roof drainage outlets

Use of a waterway or open channel as an outlet for roof gutter and downspouts permits ready maintenance and simple changing when needed. A grassed waterway is sometimes practical. A hard-surfaced drive, lined waterway, or grated opentop concrete gutter (see figs. 10–1, 10–2) withstands year-round foot and wheeled traffic. Grated, modular, preformed, drain-trench sections comparable to the U-gutter (see fig. 10–7) are available that have built-in slope and different strengths and styles of cover grates. Such opentop gutters need periodic cleanout (see NRCS Conservation Practice Standard, Underground Outlet, Code 620).

Underground drainpipe is generally made of corrugated or ribbed polyethylene plastic pipe that has a 4- to 36-inch inside diameter (fig. 12–7). This drainpipe is economical, lightweight, and durable. A smooth inside surface improves flow characteristics and reduces plugging. Plastic drainpipe is available in over 1,000-foot long, flexible coils that are up to 6 inches in diameter and in various other coil lengths for other diameters. The smooth lined pipe and corrugated pipe that is more than 6 inches in diameter are available in 20-foot lengths. Extra installation care is needed for lightweight pipe to reduce crushing from trench protrusions and backfilling. Consult manufacturer's recommendations and Natural Resources Conservation Service (NRCS) construction engineers for proper installation technique.

Heavy, but strong and durable, concrete drainpipe that is 0.5 foot to 6 feet in diameter is available in up to 10-foot sections. Concrete pipe resists soil movement, heavy crushing loads, and corrosion. Hoist equipment is needed for installing the larger concrete pipe.

Corrugated steel or aluminum culvert is made in 1- to 12-foot diameters and up to 8-gage thickness, depending on size. A 16-gage (0.0598 inch) steel is common. (Corrugated and sheet metal thickness is often stated in gage thickness. As the gage number gets larger, the metal is thinner.) The size of the culvert depends on available soil cover or height clearance (see fig. 8-8), flow rate required, and if the outlet can free flow or is submerged.

Various inlet and outlet pieces, corners, and other fittings are available to aid drainpipe performance, safety, and maintenance. A removable, screened outlet, for example, reduces pest entry and plugging. Pipe drains installed belowground need clear identity aboveground to prevent their being misaligned or crushed by heavy loads or accidentally damaged in future excavation. Cleanouts need to be marked so they are noticeable above snowdrifts and weed growth (see NRCS Conservation Practice Standard, Underground Outlet, Code 620).

More information about specific needs and design of culvert systems is in the Handbook of Steel Drainage and Highway Construction Products (Amer. Iron & Steel Ins. 1993).

651.1203 Waste collection equipment

Waste collection systems are described in chapter 9 of this handbook, and components for waste collection at the farmstead in section 651.1002. Collection of vegetative wastes involves equipment types such as rakes, stackers, bale bunchers and haulers, brushcutters, and choppers, and a description is not included here.

(a) Hand scrapers, shovels, brooms, washers

Common waste collection chores include washing, disinfecting, and cleaning in corners, surfaces beneath fences, along partitions, in alleys, and in stalls or pens. Regularly cleaned, neat-appearing facilities reduce complaints about odors, insects, and other pests (see appendix 8A, section 651.0850). Warm, moist, manures are ideal for pests and need to be frequently and thoroughly removed. Flies, for example, are a noticeable nuisance, especially during warm weather when the egg-to-adult fly cycle is completed within 10 to 14 days.

Shovels, forks, scrapers, brooms, brushes, pressure-washers, and related hand tools (fig. 12–8) are needed for small area cleanup. A variety of hand tool heads and handles are available with handle angle (lie) and length variations for individual needs. A straight-grained ash wood or fiberglass handle provides strength, grip, protection from electric shock, and handling comfort. A short handle with an end D-grip permits heavier lifts and working in close quarters. A long handle provides better leverage for digging and throwing.

Aluminum and plastic shovels are lightweight, rust-proof, and nonsparking. The extra investment required and the relatively faster wear compared to steel should be considered in choosing these shovels.

Forks are available with forged flat, oval, or round tempered steel tines in 3-, 4-, 5-, and up to 12-tine (18-inch) widths. These forks handle loose or heavy, wet wastes. The flat tines assist in getting under and holding coarse, chunky waste. The oval tine is stiff, and the round tine forks do not clog as easily as the flat or oval ones.

A long-handled, relatively heavy, floor scraper minimizes the labor of loosening stuck-on materials. Lightweight squeegees and scrapers are designed for cleaning and drying wet, smooth surfaces. A scraper blade that can be reversed when worn doubles the blade life.

Long, upright-handle brooms are used to sweep corners and small spaces, even wet areas. Push brooms that are up to 2.5 feet wide assist fast cleanup of large areas. A broom that has short, flexible bristles is designed for sweeping lightweight dirt and dust from smooth surfaces. The long, stiff bristles are for rough, tough sweeping. Plastic bristles resist moisture and bacteria, but not heat. A secure head for the bristles and handle attachment assists broom durability. The chemical, solvent, fat, and oil resistance of the bristles should also be considered in choosing a broom. A flow-through handle assists in washdown cleaning.

Pressure washers (fig. 12–8) can provide up to 4,000 pounds per square inch of water pressure to loosen and wash away hard, dried, stuck-on waste. Washers that have an optional electric, gas, or oil heater can heat the water or produce steam to help speed waste removal (table 12–1). A fuel per hour rating is the measure of their efficiency.

Table 12–1 Typical pressure washer manufacturer's data

horsepower	volts	amp	psi	gpm	hot water
1.5	115	13	1,000	2.2	no
2	115	18	1,500	2.1	yes
3	230	—	1,500	3.0	yes
3.5	gas	—	1,500	2.2	no
5	230	—	2,000	4.0	yes
5.5	gas	—	2,000	3.0	yes
6	240	—	2,500	—	yes
7.5	230	—	3,000	4.0	yes
7.5	230	—	2,500	5.0	yes
9.0	gas	—	2,400	3.7	no
11.0	gas	—	3,000	4.2	no
13.0	gas	—	3,000	4.0	no
18.0	gas	—	4,000	4.0	no

Pressure washer selection considerations include:
- cost,
- kind of cleaning desired (grease soil),
- pressure durability of the surface to be cleaned,
- water supply quality and quantity needs,
- cleaner-aid injection,
- portability,
- hose insulation and length,
- heater fuel type,
- washer corrosion protection, and
- available power source.

Electric power is convenient, quiet, and generally available, but circuit capacity might be limited. Internal combustion engine-powered washers are useful in a wide range of locations; however, they need adequate exhaust gas ventilation to prevent carbon monoxide (CO) accumulation when used indoors. A freeze protected, inplace pressure washer pipeline, strategically placed in quick-connect plug-in locations for an easily moved pressure washer head, helps in areas that need frequent cleaning.

Figure 12–8 Hand tools used for waste collection

(b) Tractor scraper blades

Scraping and collecting wastes with a tractor rear- or front-mounted blade is relatively fast over large, flat areas. Tractor scraping requires operator time, however, and takes a tractor away from other uses.

A rear-mounted tractor scraper blade, 12 to 18 inches in height, permits corner cleanout and smooth, fast, straightaway operation (fig. 12–9). Available in 4- to more than 10-foot widths, the size selected needs to match the tractor weight, hitch design, hydraulic system, and alley space. The replaceable, high-carbon steel blade used on many tractor rear scrapers is needed to clean off dried, packed-down or frozen waste. Frequent scraping is needed in subzero weather to reduce frozen waste buildup. A rubber-edged blade can be used to clean off wet, roughened concrete surfaces, but it slides over stuck-on waste. A diagonal or diamond-shape groove pattern on concrete surfaces reduces slippage and minimizes scraper bounce and metal blade wear (see fig. 12–22).

Most rear scraper blade models can be rotated horizontally right or left, as needed, to direct the waste flow into a row for temporary storage or to simplify loadout. A hydraulic powered, 3-point hitch is common with rear mounted scraper blades. Other models can also be tilted and adjusted side-to-side and rotated 180 degrees for reverse pushing (figs. 12–9, 12–10). Blade curvature and tilt adjustments aid waste flow while scraping.

A 1- to 2-inch depth of semi-solid or slurry waste on a paved alley fills a scraper blade and spills out the ends after scraping about a 10-foot length. A box type scraper (fig. 12–10) can increase scraper travel distance three to five times before end spillage begins. Box type scraper models have end pieces and up to 32-inch-high blades to hold in waste. Beside mechanical or hydraulic control options, different blade tilting and reversing options are available.

Large (up to 8-ft. diameter) discarded earthmover equipment tires can be used to scrape slurry and semi-solid waste from long, wet alleys (fig. 12–11). The tires are cut in half with the tire sides removed, and are then mounted on the towing frame. They are available as tractor front-end loader push, as push-only, and as 3-point hitch tow models. An inside scraper height of 16 inches maximizes the slurry holding capacity without end spillage. A smooth, straight-cut edge on the tire side is essential to avoid scraper blade bounce and leakage.

Figure 12–9 Tractor rear scraper blade with vertical tilt (courtesy Worksaver, Inc.)

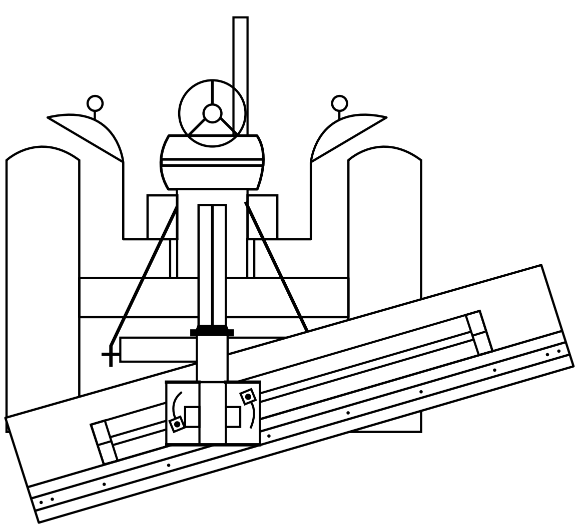
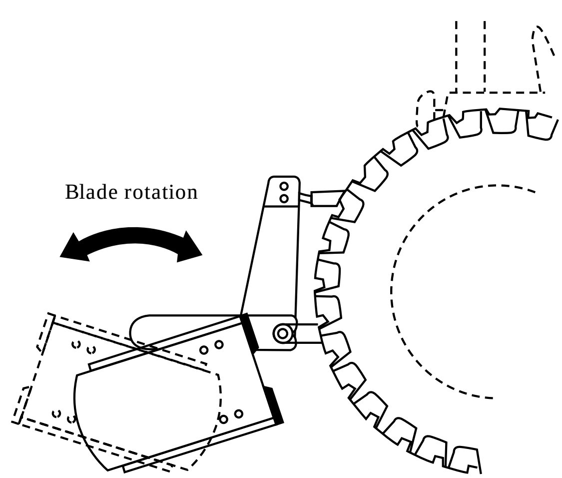


Figure 12–10 Box type slurry blade scraper; rear-mounted model (courtesy Degelman Industries, Ltd.)



(c) Lawn and garden size tractor scraping

A lawn and garden or compact tractor scraper has advantages for access, visibility, and agility over the larger tractors, but the capacity is less (fig. 12–12). The small tractors have a wide selection of other useful attachments for sweeping, mowing, and dust and dirt collection. Electric, gasoline, and diesel-powered units are available in sizes of up to 25 horsepower.

(d) Tractor front-end loaders

A tractor front-end loader (fig. 12–13, also see fig. 9–20) is perhaps the single most used multipurpose equipment item for waste handling. Useful for scraping, collecting, and agitating most types of wastes, it is indispensable for loading solid and semi-solid wastes for hauling. Various attachments are available for all sizes of tractor power. Typical 30- to over 100-horsepower agricultural tractors and low clearance, compact tractor loaders are more widely used for waste handling in and around facilities. Live, high-capacity, hydraulic power on tractors is basic to loader development and use. Buckets, forks, blades, and other implements (fig. 12–14) are readily attached to and detached from the loader frame.

In addition to the available attachments, the following characteristics should be considered in selecting a tractor front-end loader:

- Lift capacity
- Breakout force
- Lift height
- Clearance when dumped
- Dump angle and the time needed to raise and lower

The measurements designated in figure 12–13 are standard operational specifications used by manufacturers based on the ASAE Standard S301.2, Front-end Agricultural Loader Ratings (ASAE [c] 1991). These measurements provide a comparison standard for loader selection. For example, a comparison of over 200 typical tractor loader models indicates maximum lift height (A) ranges from about 6 to 21 feet clearance with attachment dumped (B) ranges from 52 to 183 inches, and maximum dump angle (D) varies from 6 to 98 degrees (Hudson 1993).

A loader is often described by the manufacturer in terms of its horsepower and recommended usage. The loader frame design and construction are for light or heavy duty. While many models are rated at about a 2,000-pound capacity, full height lift capacities are available to nearly 5,000 pounds. However, at this

Figure 12–11 Tractor scraper blade using earthmover tire (courtesy Tillamook Concrete Groving)

Figure 12–12 Lawn and garden tractor scraping equipment (courtesy Kubota Tractor Corporation)

capacity, the tractor framework, traction, and overturning are limitations. Elements to consider in selecting a loader are the operator's view, quick attachment, clearances, operating speed, and joystick type hydraulic control.

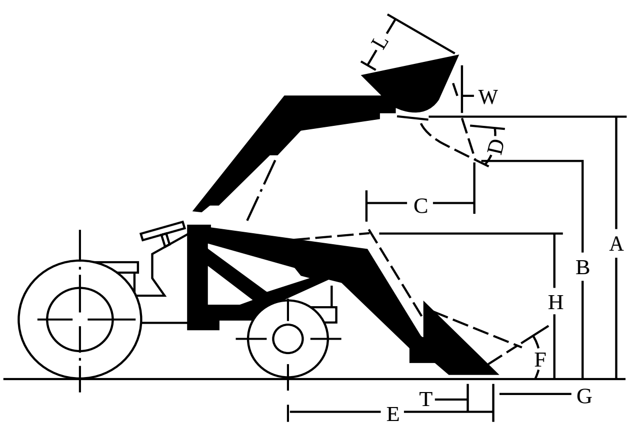
The ASAE Standard 355.1, Safety for Agricultural Loaders, relates basic rules for safe tractor front-end loader operation (ASAE [j] 1991). Some of the rules include:

- Four-wheel drive and wide-spaced front tractor wheels are more stable than tricycle-type tractors.
- A loaded bucket reduces rear wheel traction and limits efficient use to areas with slopes of 10 horizontal to 1 vertical or less.
- Usefulness is hindered with building and yard layouts that require backing down long alleys or that have difficult turns.

The following operation and maintenance items are important for efficient front-end tractor loader use:

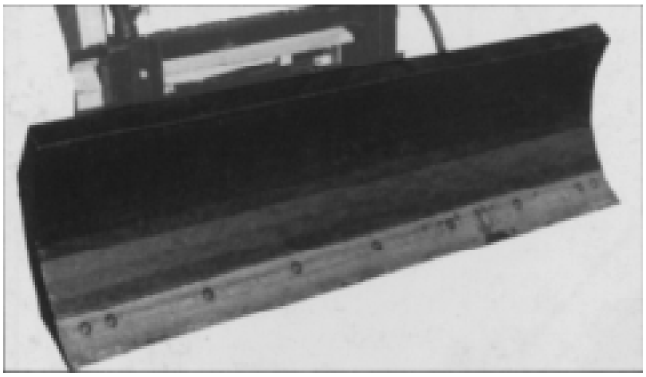
- Tires are properly inflated.
- Tractor steering and hydraulic systems are maintained.
- Extra front-end tractor weight are not used.
- Rear wheel weighting and wide tire setting are in place.
- Hydraulic pressure relief valve operation should be avoided (hastening fluid breakdown).
- All moving joints are regularly lubricated.

Figure 12–13 Tractor front-end loader measurements

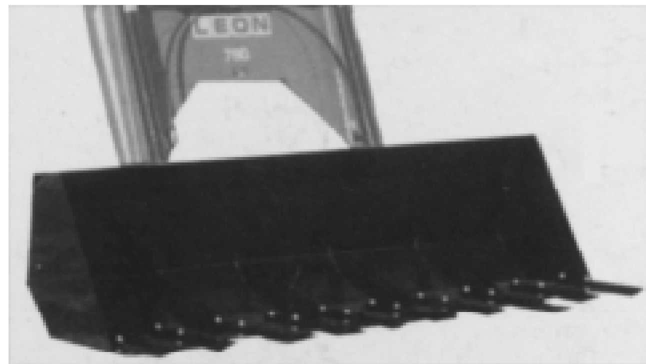


A – Maximum lift height
B – Clearance with bucket dumped
C – Reach at maximum height
D – Maximum dump angle
E – Reach with bucket on ground
F – Bucket rollback angle
G – Digging depth
H – Overall height in carry position
L – Length of bucket
W – Lift capacity to full height

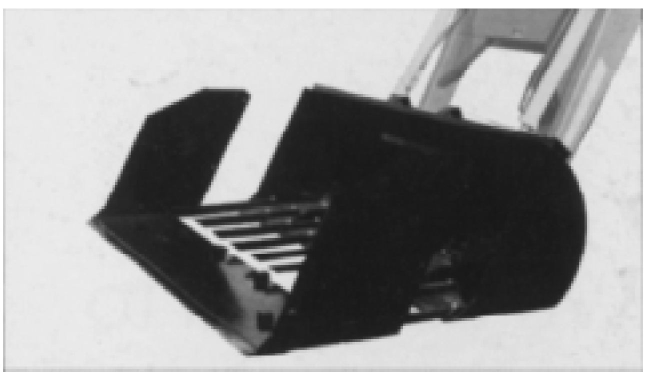
Figure 12–14 Tractor front-end loader attachments (courtesy Leon Mfg. Co.)



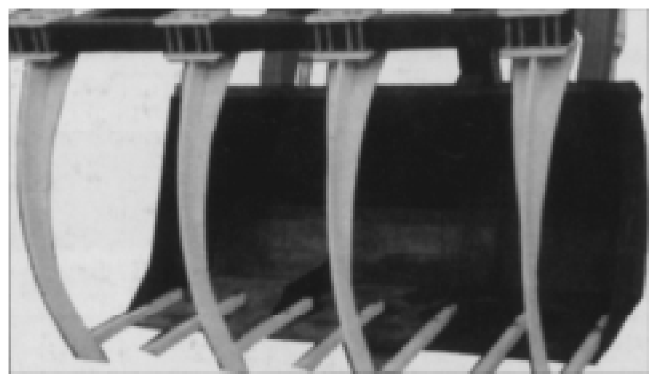
Blade



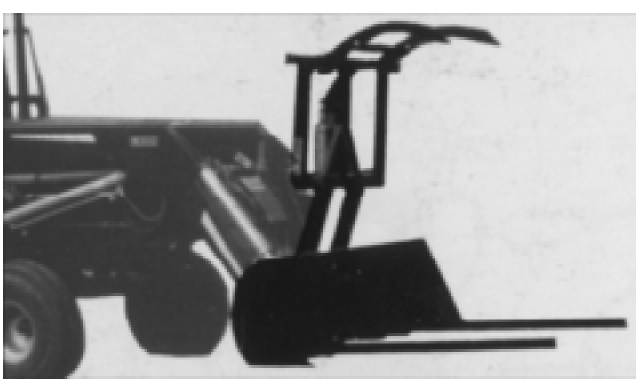
Scoop



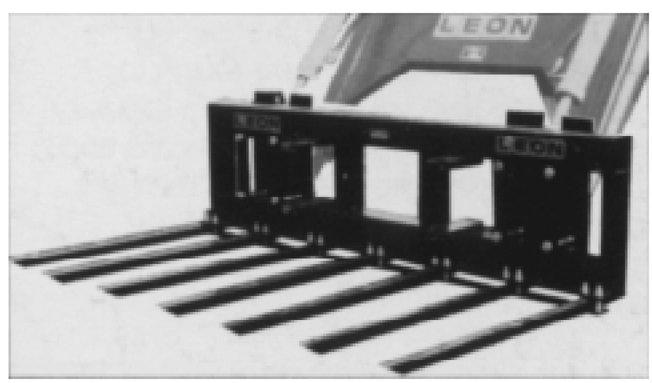
Bucket



Claw



Handler



Fork

(e) Skidsteer and articulated loaders

Compact skidsteer and articulated-steer loader tractors are especially designed for scraping and loading semi-solid and solid wastes in small spaces (fig. 12-15, see fig. 10-42). The front-end lifting arms, with a selected attachment, are integral with the tractor. Most skidsteer tractors can turn 360 degrees in their own tracks. The longer wheelbase, medium compact, articulated-steer tractor loader needs more turn space, but it gives a smoother ride (less spillage) and has a higher reach.

Skidsteer loader sizes vary according to horsepower and rated operating load. The Society of Automotive Engineers (SAE) J818 Standard sets their rated operating load at half the tipping load. The tipping load is the most weight the loader can lift without tipping forward. The rated operating load is well within limits of safe operation. The loader can lift more if carefully handled, however, the rated value is a basis for size comparison. The 1,000- to 1,500-pound capacity range is relatively popular, but loaders that have more than a 4,000-pound lifting capacity are available.

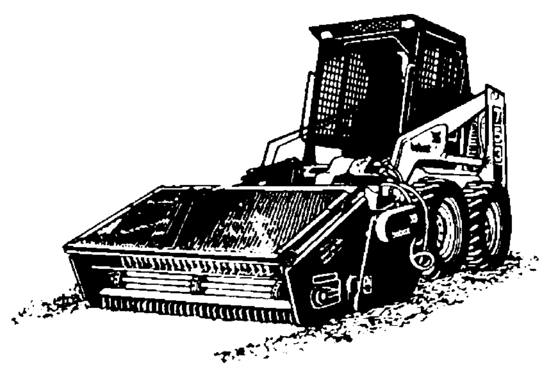
Beside the investment, major considerations in selecting a loader are:

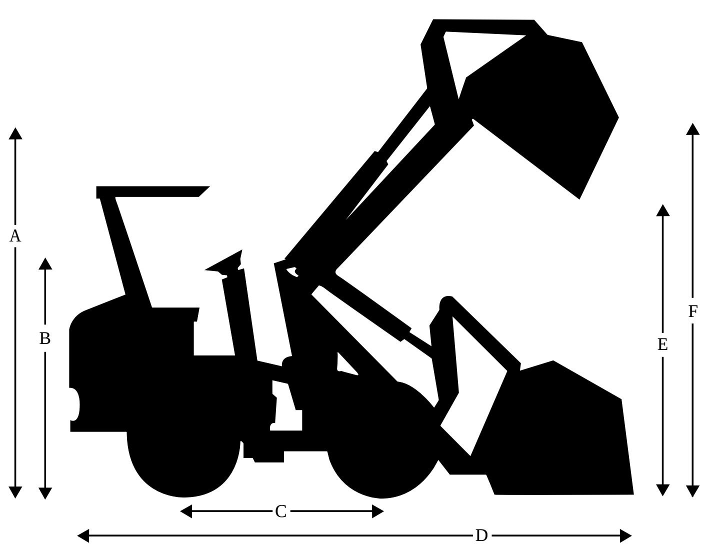
- load rating (capacity and tipping),
- turning radius,
- length/width sizes,
- power,
- noise, and
- available attachments.

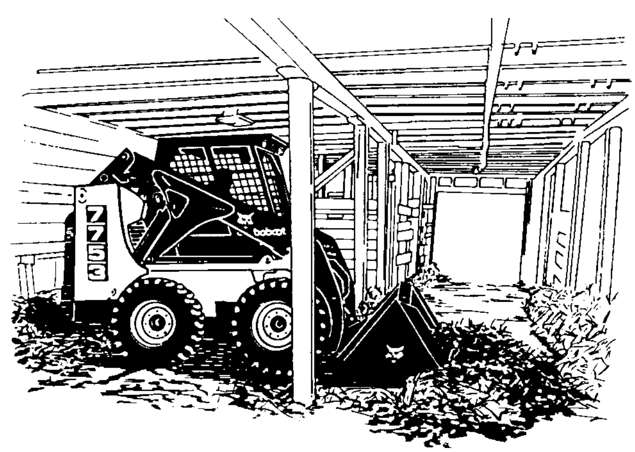
Figure 12–15 Skidsteer and articulated-steer type loaders (courtesy Melroe Company and Northwestern Motor Company)

Model Dimensions

	T15	T25	T50	T75
A	82" (2082 mm)	83 1/2" (2121 mm)	93" (2362 mm)	111" (2819 mm)
B	61" (1549 mm)	63" (1600 mm)	70" (1778 mm)	86" (2191 mm)
C	48" (1219 mm)	52" (1321 mm)	58" (1473 mm)	72" (1829 mm)
D	137" (3479 mm)	162" (4115 mm)	176" (4770 mm)	208" (5283 mm)
E	83" (2108 mm)	88" (2235 mm)	96" (2438 mm)	102" (2590 mm)
F	104 " (2642 mm)	110" (2794 mm)	120" (3048 mm)	138" (3504 mm)







Overall height and width clearances are important for maneuverability. A loader bucket width, the same or wider than the tractor width, aids steering when scraping; and reduces tracking spilled waste. Buckets range from 3 to 6 feet wide.

Rubber, steel with rubber pads, and steel grouser tracks are available to fit over the tractor tires. These tracks improve traction and flotation and provide a smoother ride, depending on the working surface.

(f) All-wheel drive front-end loader

The investment involved in purchasing a large, high-capacity, all-wheel drive bucket loader (payloader) is justifiable for a year-round, near daily operation (figs. 12–11, 12–16, and 12–17). This type loader is best adapted to open yard cleaning and to handling heavy and bulky materials around big work areas with high headspace. Durability, high lift, and relatively fast high-capacity operation are major features. Four-wheel drive is basic, with articulated-steer or crabsteer as options. Available models range from 60 to more 275 horsepower and have a 1- to 8-cubic-yard load carrying capacity. A 5-cubic-yard bucket capacity is common. Loaders with interchangeable buckets and forks generally have less loading capacity than that of the fixed bucket models. Most are diesel powered.

A telescoping-frame type boom or bucket loader reduces transmission shifting and much of the wheel movement and speeds up loading and piling (fig. 12–17). The reach is a major feature.

Cattle feedlot cleanout and waste loading are often done using the telescopic, all-wheel drive loader. The operator must be skillful in the use of this loader to efficiently collect waste on an unpaved lot (usually with some wet and some dry areas) and yet leave the compacted waste and soil layer. Shifting gears four times per bucket load while travelling in a forward-reverse, forward-reverse motion and simultaneously steering the loader, plus guiding the vertical movement of the bucket, can be tiring.

The most efficient method for annual waste collection in open, large Texas feedlots was determined to be chisel-plowing the feedlot to reduce chunk sizes, stacking the waste in the pen with a wheel-type loader, and then loading and hauling the waste on trucks. However, this chisel-plow, all-wheel drive loader method can disturb the compacted waste and the soil interface seal needed to protect against nutrient leaching (Sweeten 1984).

Figure 12–16 All-wheel drive (agricultural bucket loader)

(g) Motor grader

A common road grader and maintainer can be practical for frequent scraping of solid waste buildup on long paved aprons and open yard surfaces. Although a large turn space is needed, this equipment is designed for scraping and has the adjustments, visibility, capacity and other features needed to scrape big areas. In dry climates the smooth surface left by the grader blade facilitates frequent waste collection. Like the self-propelled, elevator scraper (see fig. 12–18), the accurate control of the scraper blade minimizes disturbance of the sealed soil surface layer.

(h) Elevating type box scrapers

A self-loading elevator type scraper-hauler (fig. 12–18) that both loads and hauls is more efficient than an all-wheel drive loader for cleanout of soid waste from large open feedlots with few corners. The ability of the elevating scraper to make a precise cut permits slicing through built-up solid waste while leaving the desired undisturbed waste and soil sealing surface layer. The operator can travel continuously forward in an oval-shaped pattern, rather than the forward and reverse cycles needed with the all-wheel drive loader (Sweeten 1991).

A self-propelled elevating scraper has an 11- to 25-cubic-yard loading capacity and 100- to 250-horsepower moving capacity. Similar size towed models have less capacity and power need. Models are available with varied wheel arrangements, height and width clearances, hitching and loading transfer features, dumping or push-off unloading features, cutting depth control, and hydraulics options. A compact adaptation of the elevating scraper for poultry litter agitation and hauling is called a cruster (see fig. 12–50).

The wheeled, tractor-towed, conventional box-scraper is useful for collecting loose solid waste in open yards, constructing mounds, and performing drainageway maintenance (Livestock 1979). The operating capacity generally is lower than that for a comparable sized, self-loading elevating scraper. The scraper's capacity ranges from 1- to about 8-cubic-yards, and the power needs are about 25 to 450 horsepower, depending on operating speed and hydraulic capacity. A useful model for working around the typical facility is about 5-cubic-yards and 100-horsepower capacity.

Figure 12–17 Telescopic, all-wheel drive bucket loader (courtesy Gehl Company)

(i) Mechanical scrapers for gutters and alleys

Open scrape alley design for semi-solid and slurry waste is explained in section 651.1002(a). The relatively light duty cable-drive scraper (fig. 12–19) can use manual or automatic control of a 0.75- to 1.5-horsepower electric motor. Automatic control is generally set to reverse or shut-off the power when the scrapers reaches the end of the set travel distance or overloads from an obstruction. Alley scraping arrangements can be designed so one drive can power several scrapers at once (fig. 10–3). Operation is quiet, and alley corner turns can be made right or left.

To reduce corrosion and weight, a high-strength stainless steel cable, 3/16 to 5/16 inch in diameter, is used for pulling the scraper. The size used depends on the scraper width and length. Small diameter cable, with adequate strength, is more flexible around corners than larger steel cable, and the investment is less. Cable stretching requires periodic adjustment.

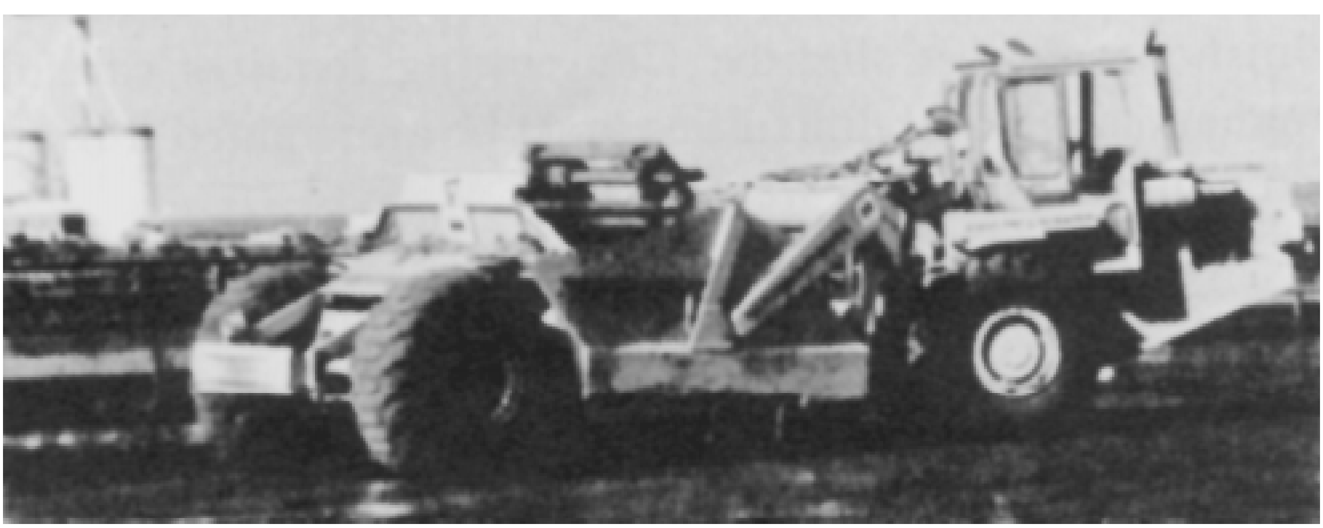
Cable-drive power units are available for alleys that are up to 1,000 feet long. Scraper blades up to 12 feet wide and 8 inches high are available. Most are made from corrosion-resistant steel. Some models have a flexible material on the scraper edge for cleaner scraping of a rough surface.

Scraper speeds of 4 to 8 feet per minute are practical for open alley scraper travel. Speeds to 50 feet per minute are used with slurry waste below a slat floor where there is no foot traffic interference.

Most models scrape one way, then tip or fold up and return empty. Rigid blade models push the waste each way and require a collection gutter at each end of travel. Minimum clearance at blade ends and construction of a uniform alley floor minimize leakage or spillage of scraped waste. A scraper blade pushes only so much semi-solids, and then it overflows. Because of this, frequent operation is needed; however, the frequent use increases drive, cable, and scraper wear and hastens floor wear and slipperiness.

A wide and long alley scraper for semi-solid waste needs a heavy-duty link chain. The chain generally is set in a preformed groove in the alley floor to pull a 7- to 10-inch high scraper blade (fig. 12–20, see fig. 9–6). The chain drive is similar to that used with a gutter cleaner (fig. 12–21). Heavy-duty chain links are forged and heat-treated from high carbon steel. Hook-type chain links can flex in all directions. Alloy steel pintle connected chain is used for corrosion resistance and mostly horizontal movement.

Figure 12–18 Self-propelled elevator type scraper-hauler



A chain drive intermittently operated in wet waste corrodes, wears, and stretches over a few years of use, especially where the alley is long and wide or the waste is dense. This wear demands periodic maintenance of the chain and replacement about every 8 to 12 years.

The concrete of open, scraped concrete alleys is grooved when the alley is constructed or later using a concrete saw. The grooved concrete helps to reduce slipperiness. The grooves are about 0.375 inch wide and deep. They are spaced 4 to 8 inches apart and are diagonal to the scraper travel, which helps to make the scraping smoother and cleaner (fig. 12–22). Too deep or wide grooves interfere with cleaning and disinfecting, which can affect foot health.

In some cases loose aluminum oxide grit (as on sandpaper) is worked into the surface of the fresh concrete instead of grooving the concrete. The grit is applied at 0.25 to 5 pounds per square foot. Coarse grit of 4 to 6 meshes is recommended. Such grit surfaces increase scraper wear (Barquest et al. 1974).

The widely used gutter, or barn cleaner, designed for collecting semi-solid and solid waste, generally uses a continuous, one-way heavy chain drive (fig. 12-21, see fig. 10-10). The less-used back and forth shuttle-stroke cable or rod pull type (fig 10-9) costs less than other cleaners and only needs 1 to 2 horsepower and manual control. Its practical use is with a relatively short gutter and slurry waste where up to 140 feet per minute speeds are used.

The heavy-duty one-way driven cleaner requires 2 to 10 horsepower, depending on gutter width, length, and the cleaner speed. The gutter generally is 16 to 18 inches wide. It is usually 12 to 18 inches deep. The gutter chain can be up to 700 feet long. The typical speed for this cleaner is about 20 feet per minute.

Scraper paddles that are 2 to 4 inches high and spaced 1.5 to 4 feet apart are available. Higher paddles and closer spacing are required for slurry and liquid waste. Corner-wheel construction, installation, and maintenance are critical because the system experiences major wear in these areas. Reverse turns are located where the unloaded chain runs empty on its return.

Figure 12–19 Cable-drive scraper for open alley or under slat floor (courtesy of Acorn Equipment Company)

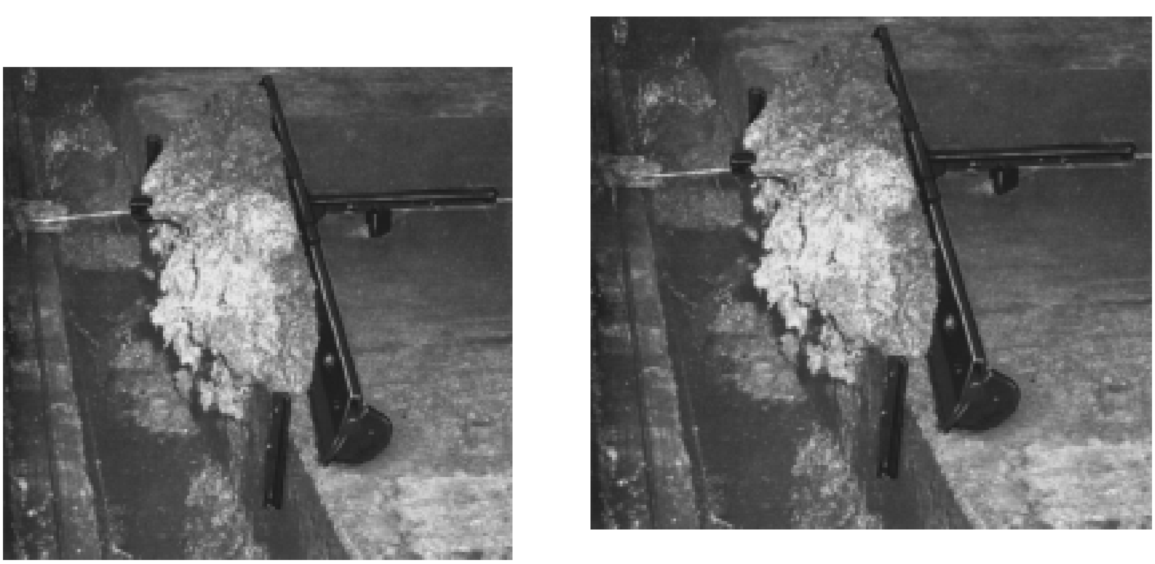
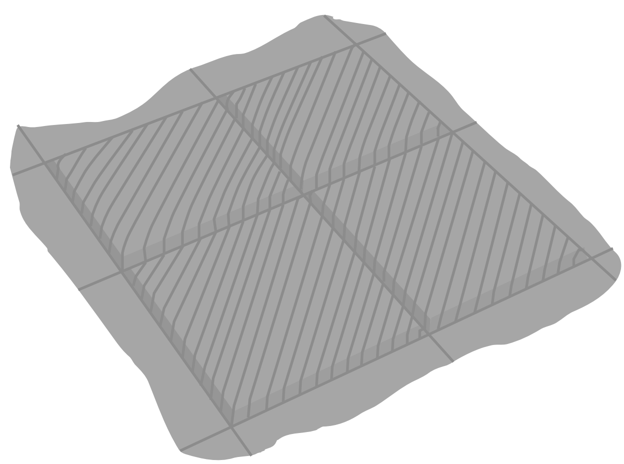


Figure 12–20 Heavy-duty alley scraper, chain drive (courtesy of Alfa Laval Agri, Inc.)

Figure 12–21 Heavy-duty alley gutter cleaner with chain drive (courtesy Patz Sales, Inc. and Husky Farm Equipment, Ltc.)

Figure 12–22 Diamond-shaped concrete floor grooves



(j) Conveyors and stackers

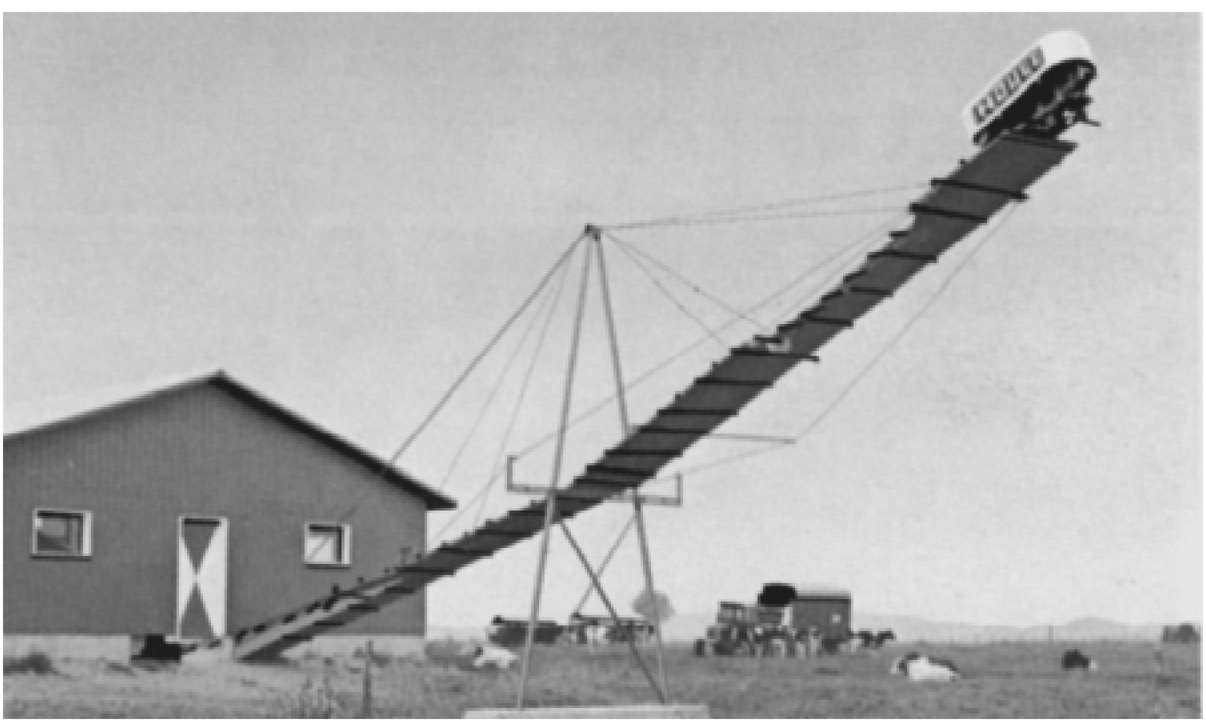
Most gutter cleaner equipment has unloading elevator ramp options for piling or stacking solid and semi-solid waste onto outside storage piles and aboveground storage tanks (see figs. 8–22, 10–12, 12–21). A wheeled undercarriage or overhead cable suspension support of the ramp permits semi-circle movement of the elevator for more storage space (fig. 12–23). A picket dam (see fig. 12–36) or other method (see fig. 9–7) may be needed for drainage to storage. See section 651.1005(d) of this handbook for additional information.

Clean-off options for semi-solid waste that sticks on paddles is part of gutter cleaner equipment. Melting snow or rainwater drains down an unprotected, inclined conveyor and into the gutter. Stacking fresh waste on old increases the rate of decomposition and nutrient loss and increases odor, pest, and frozen waste buildup problems; however, the temperature of the resulting stack must be carefully monitored to prevent spontaneous combustion. Temperatures near 160 degrees Fahrenheit are indicative of problems.

An endless chain-slat type conveyor adapts to inclined elevating of scraped or separated solid waste to aboveground storage. It is used as part of the inclined screen solids/liquid separator (see fig.12-62). Semi-solid waste leaks liquid, sticks and dries on the chain and slat surfaces, and dribbles off or freezes on the return. The 5- to 10-horsepower need for a 30-foot lift is less than that required for an auger; however, the capacity is also less because the waste tends to slide or roll back down the incline. Typically, a 5 horizontal to 3 vertical slope is about the maximum elevating angle for a chain-slat conveyor, depending on slat design. A chain-slat speed of 75 to 125 feet per minute is typical.

Slurry and liquid wastes are best directly pumped or conveyed up at a less than 30 degree angle to storage with an enclosed auger. The capacity of an open-top, U-trough auger is increased if the auger is operated at flatter inclines. Although augers are operated at steep slopes with liquid waste, auger power requirements for semi-solid waste are high, about 1 horsepower per 2 feet of auger length for a 13- to 16-inch diameter auger at 200 rotations per minute.

Figure 12–23 Gutter cleaner conveyor stacker that is cable supported (courtesy of J. Houle & Fils, Inc.)



Powered thrower, or slinger, waste stacking equipment was once made for piling semi-solid waste conveyed onto it via a gutter cleaner. The power requirements were relatively high, and winds affected pile placement and development. Appearance and frozen waste buildup with regularly top-piled waste were also problems.

(k) Flushed gutters and alleys

Flush gutter and flush alley waste collection uses a relatively large quantity of regularly added flushwater for more thorough cleaning. Gutter or alley design and flushwater quantity are explained in sections 651.0403(k) and 651.1002(a) and (b) and in table 12–2. Different applications are shown in figures 9–9, 9–18, 10–4, 10–5, 10–6, and 10–23. A flushwater recycle arrangement (see fig. 12–28) reduces the amount of added fresh water.

In lieu of scrapers with mechanical power and control, flushing equipment involves pumps [see section 651.1206(b)], pipes, tanks, drains, and liquid overflow control. Electric power that allows automatic control is often used. A stored flushwater release valve needs to deliver flushwater to a gutter at the correct flow rate for a necessary length of time [see section 651.1002(a)(2)]. Several types of gutter or alley flushwater storage and release equipment are used. Which to use depends on investment, facility design, flushwater demand, and waste quality. The equipment can include:

- tip or dump tanks,
- storage tank gate valves,
- siphon-release storage tank, and
- tower-type storage with pipeline or valve flow control.

An ordinary stock watering tank, portable plastic tank, or used metal tank is adaptable for flushwater storage or release. Aboveground flushwater storage tanks are often locally custom built using poured-in-place or precast reinforced concrete, concrete block, or fiber glass. In flush alley cattle barns, the alley flushwater storage tank can also be used as a cattle waterer where fresh water is used. A gate-type flush tank door on the side (fig. 12–24) or flop-up valve on the bottom of the storage can be hand operated or semiautomatic operated using float-controlled weight assist, vacuum pump assist, or air pressure assist. A watertight seal and smooth door or gate operation are elusive features requiring workmanship, durable materials, and maintenance.

Dump-type flush tanks (fig. 12–25, see fig. 10–6) are manufactured or can be custom built from a plan (appendix 12A). These tanks are relatively low cost and can be readily changed or replaced. Such tanks can automatically dump when steadily filled to an adjustable, overbalance pivot-point. Bearing wear, sticking, tank corrosion, noise, floor space need, and splashed water are considerations when choosing a dump-type flush tank.

Unlike a dump-type flush tank, an automatic siphon flush tank generally has no moving parts (see fig. 10-6). The operation of this type flush tank is explained in section 651.1002(a)(2). An interruption of flushwater flow (e.g., power or pump failure) stops the automatic siphon action. A burping using a compressed-air blast through the siphon may then be needed along with resumed waterflow to restart the automatic siphon action. The investment is relatively high for a siphon. Unlike a dump-type flush tank, the siphon can be located overhead with a drop pipe outlet, which eliminates the use of building floorspace.

Table 12–2 Flushwater flow and pipe size (MWPS 1985)—Maximum velocity = 2.5 ft/s

Pump capacity (gpm)	Minimum pipe diameter (in)
10	1.5
20	2.0
30	2.5
50	3.0
75	3.5
100	4.0
200	6.0
400	8.0
600	10.0
800	12.0
1,000	15.0

Figure 12–24 Hand operated storage gate flush control (courtesy of Agpro, Inc.)

Figure 12–25 Flushwater storage tank with dump-type release (courtesy Agpro, Inc.)

Air leakage and foreign material that restricts flushwater flow are siphon operation problems. Siphon flush tanks can be purchased, or they can be constructed from plans (MWPS 1976). Appendix 12A shows USDA Plan 6349 for a gutter flush system. Although vulnerable to puncture or cracking, molded glass fiber tanks are noncorrosive. Repair can be difficult. Stainless steel tanks are also noncorrosive, but generally more costly.

Note: Mention of plans is only for planning information. Natural Resources Conservation Service procedure requires design analysis for specific site conditions.

An overhead or tower type flushwater storage tank, or reservoir, saves floor space, adds to flushwater pressure, and permits large volume flushing by pipes of several gutters from one water source. A sturdy, post-beam or other type tank support system is essential to hold the 2,000 to 5,000 gallons (8 to 21 tons) of overhead flushwater storage.

A tall, narrow, aboveground flushwater storage tank arrangement (fig. 12-26) is advantageous for large facilities that have several gutters or for several adjoining barns that collectively use a large volume of flushwater. Flushing can then be done at different times in the different gutters via pipes and valves from one flushwater source. A relatively small capacity fill pump, automatically operated by float switch over several hours, can fill the flushwater storage tank. A bottom drainplug is used for periodic or operation shutdown cleanout. Also, an overflow pipe from the tank to a drain is needed as the automatic controlled filler pump shutoff can malfunction.

University of Missouri agricultural engineers have compared the equipment for five ways to release flushwater release. The study was conducted in their 98- by 202-foot, 160-cow dairy freestall barn (fig. 12-26). The flushwater effectiveness was measured from two dump-type flush tanks, two baffled air-controlled valves on pipes, and a partly-embedded 12-inch diameter pipe with seven 3- by 6-inch holes spaced across a 10-foot-wide alley (fig. 12-27). The

Figure 12–26 Tall flushwater storage for five flushed alleys (Rural Builder 1992, Patrico 1992)

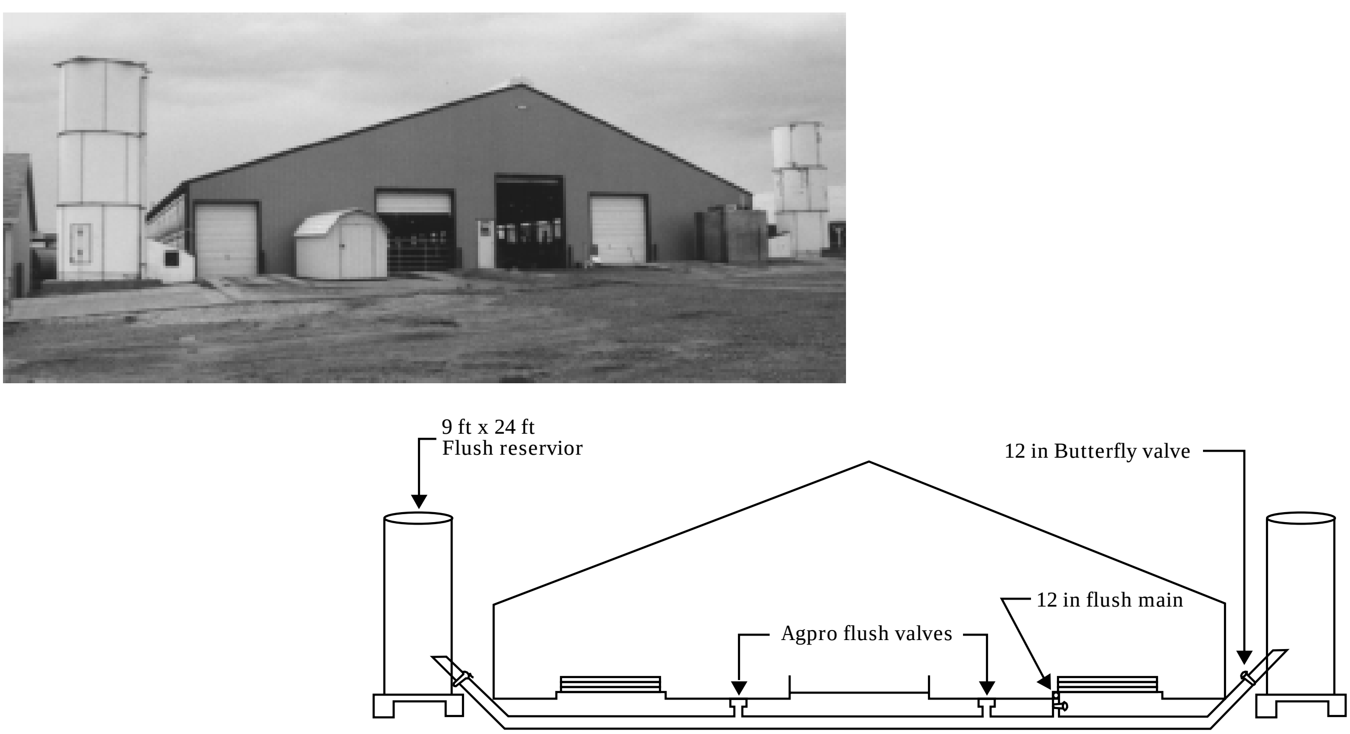
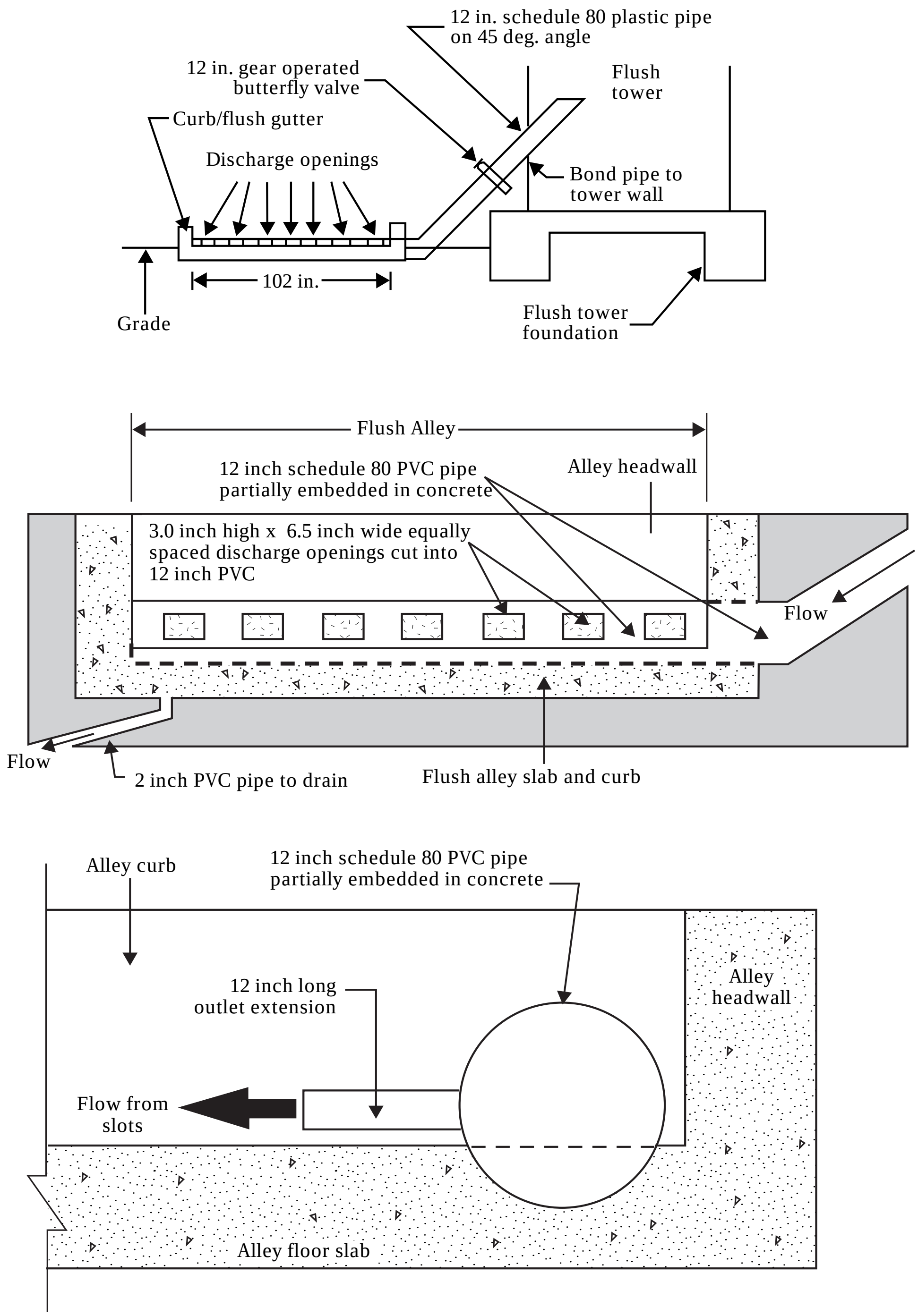


Figure 12–27 Flushwater alley entry from 3- by 6-inch holes (Rural Builder 1992, Patrico 1992)



holes had a 1-foot-long outlet extension and allowed flushwater volume to uniformly, but forcefully, exit into the alley as seven smaller streams rather than a large, concentrated stream. In daily flushing, the cleaning done by the spaced-hole flushwater discharge was preferable to the dump type flushtanks and the air-controlled pipe valve flushwater dischargers (Patrico 1992).

Direct pumping large volumes of alley flushwater from a second stage lagoon or an ample supply of freshwater is common in mild climates. Sections 651.0403(k) and 651.1002(a)(2) give more information. Table 12–2 shows the pumping capacity for various pipe sizes. Systems in use are similar to those shown in figure 12–28. (Also see figures 9–9, 9–18, 10–23.) Investment and daily operation of a large pump, such as that shown in figure 12–28, may be more practical than installing, operating, and maintaining several dump or siphon flushtanks or a large flushwater storage tank. Total water use with a pumped flush system generally is greater than that with dump-type or siphon flushtanks. A power failure or breakdown of the large capacity pump interrupts cleaning until repaired or replaced.

Figure 12–28 Large-volume, low-pressure flush pump used in a recycle system (courtesy of Gorman Rupp Company)

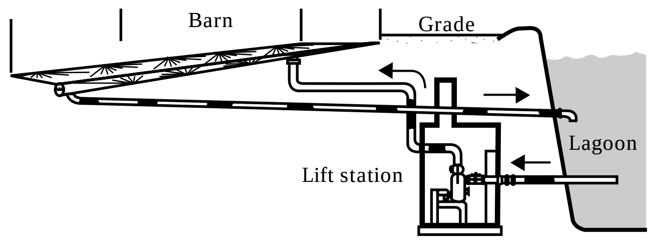


Figure 12–29 Cross gutter for alley flushwater collection

Difficulties with flushwater waste equipment include
- Pump, tank, and valve maintenance and repair
- Metal corrosion
- Struvite buildup
- Liquid freezing

In subzero climates, correct ventilation (airflow rate, direction, supplemental heating, and temperature operation) is critical to control building humidity and temper the cold drafts from freshly-pumped, cold flushwater. This is especially important for baby livestock operations.

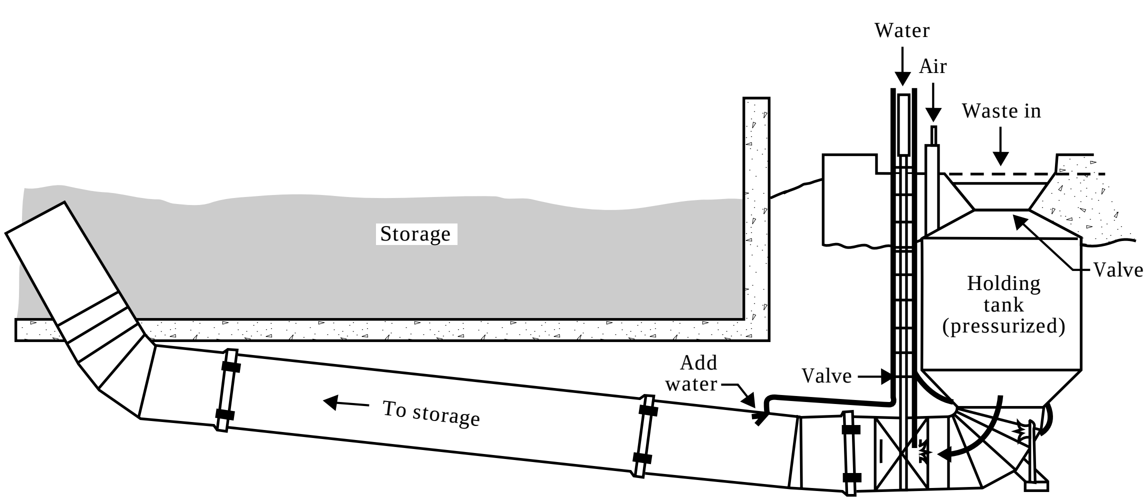
A cross gutter or drain that has adequate flow capacity is needed to smoothly carry away a large volume of flushwater from an alley or gutter (fig. 12–29, see fig. 9–9). The flow into the gutter or drain should be unrestricted. If flow is slowed, flushwater backs up and solids separate and block the subsequent flushwater.

(l) Air-pressure and vacuum waste pumping

An air-pressure (pneumatic) operated semi-solid and slurry waste pump uses a well-constructed below-ground collection or holding tank that can be closed and pressurized with compressed air (fig. 12–30). Most tanks are constructed of steel or poured-in-place reinforced concrete. Wastes are scraped into the 1,300- to 1,900-gallon tank through the top opening. When nearly filled, the top is covered and compressed air let into the tank to about 50-psi pressure. As pressure increases, the contained waste is forced out past a valve that prevents backflow from the storage. The waste moves under pressure through a 2- to 2.5-foot diameter steel pipe to storage. At least 3-horsepower of energy is needed to operate the air compressor—a larger compressor speeds airflow.

Figure 12–31 Vacuum solid waste collector and wood chipper (courtesy Crary Co.)

Figure 12–30 Air pressure chamber (pneumatic) waste pump (courtesy J. Houle & Fils, Inc.)



Although the investment for this type of equipment is relatively high, operating cost is low. Solid waste and freezing can restrict flow, and sand and excess soil in the waste can settle out and buildup in the pipe that leads to the storage tank.

Vacuum rather than air pressure is widely used for handling agricultural wastes. A PTO or hydraulic motor powered vacuum pump mounted on or inside a tanker spreader agitates and empties a slurry or liquid waste storage. The waste is agitated by simply emptying the loaded tanker back into the storage. The vacuum loaded waste is hauled and field spread with the one unit. Sections 651.1206(b) and 651.1207(a)(3) give further information.

Vacuum pumps are available in varied designs and capacities. Comparable to pumps used for liquids, vacuum pumps are rated in cubic feet per minute airflow at different negative pressure (vacuum) levels. The rotary vane type can quickly evacuate a large volume of air with reasonable power—about 10 horsepower per 100 cubic feet per minute down to about 15 inches mercury (or -7.5 psi) of vacuum.

Blower type vacuum is popular for collecting loose, dry solids where high flow vacuums of less than 10 inches are needed. Applications range from the household carpet vacuum to self-propelled street equipment. Household models simply filter out solids from the air flow. Larger capacity equipment can move the airflow through a cyclone separator where the air escapes out the top and solids drop out the bottom. Models used with agricultural waste collection include those made for a garden or lawn tractor (fig. 12-31) to high capacity, truck-mounted equipment. Their power needs range from 5 to 50 horsepower with capacity from 50 to 5,000 pounds per hour.

Although this type vacuum is noisy and relatively inefficient, the vacuum waste collection and handling is relatively clean. Screening and sorting of the accumulated waste may be needed depending on its ultimate use (see figs. 12-69, 12-70).

(m) Piston-plunger pumps

Piston pumps have been developed to convey slurry, semi-solid, and solid waste from a gutter cleaner or reception storage hopper to long-term storage (fig. 12-32, see fig. 9-6). The relatively large hopper inlet opening, piston size, and slow operation assist semi-solid waste flow. An electric motor-powered mechanical pumpjack or 2-way reversing hydraulic cylinder is used to drive the piston plunger. The positive displacement piston develops high force and moves waste through an 8- to 16-inch diameter pipe up to 300 feet away. The pipe is generally buried below frostline. Cast iron, steel, or PVC pipe are used depending on pump type and distance. Pipe jointing technique and correct pipe installation are critical. Pump chamber pressures may exceed 100 pounds per square inch, and pipe anchorage must be secure, especially at sharp corners. A pressure relief valve can malfunction, so PVC pipe failure, puncture, collapse, or plugging can be troublesome. This is especially true with solid waste, too-dry waste that expands in the pipe between pumping times, or where the waste is pumped more than 150 feet. A central location permits one piston pump to receive waste from several gutters, alleys, or buildings. Provision is usually made to add water to the waste flowing into the piston chamber. This dilutes waste and aids pipe lubrication. One scheme is to collect gray or other washwater in a sump or tank, then pump or drain this into the waste hopper when the piston pump is operating.

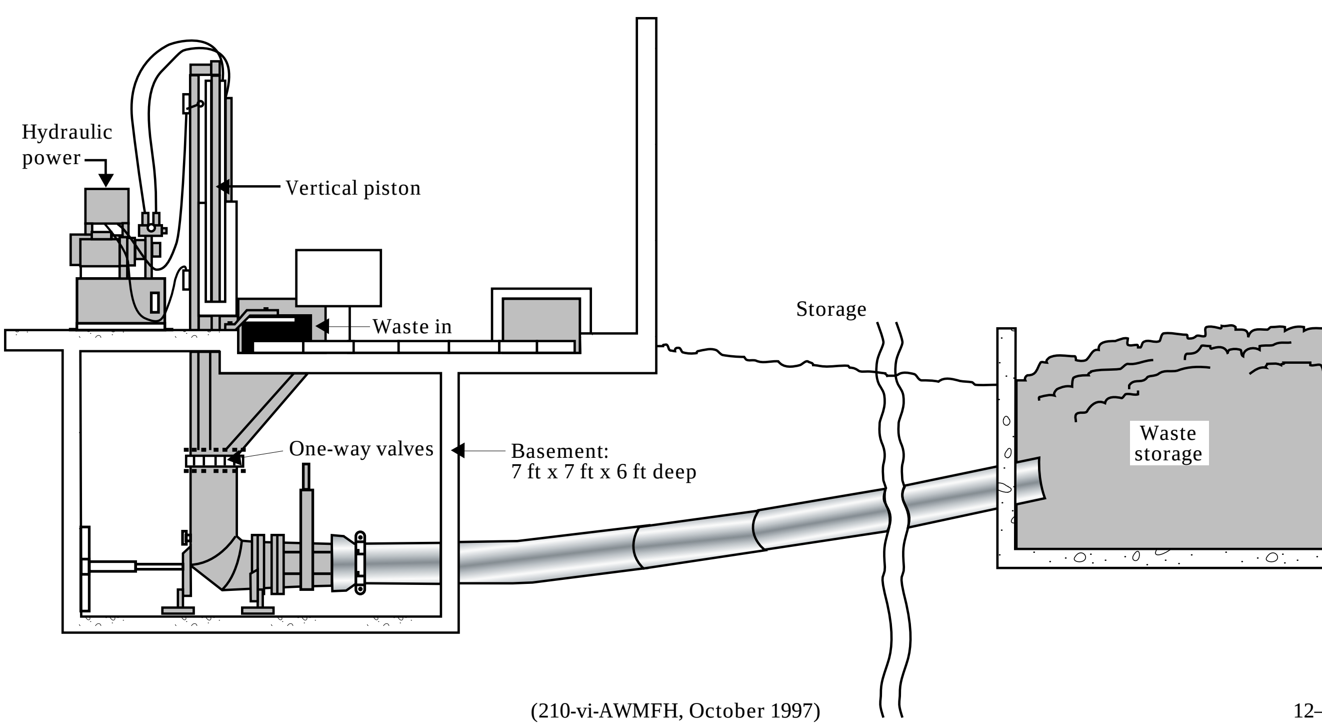
The vertical operated piston pump employs an automatic controlled hydraulic piston that moves up and down through a 3- to 4-foot stroke. It does 1.5-strokes per minute, which can move 60 to 70 gallons per minute of slurry waste (fig. 12-32). A tight-fitting, flexible, lubricated seal around the vertical piston causes it to draw semi-solid waste by suction from the fill hopper into the piston chamber. Waste that is solidified, such as frozen chunks or straw, will not flow into the piston chamber. A rounded, smooth hopper is helpful in these situations. A belowground basement, about 7 square feet, is used for the hydraulic pump and fill hopper. It also can be used for maintenance and repair. Although the basement is an extra investment, it frees up space on the main floor.

The slant operated piston pump (see fig. 9-6) uses a hollow piston that is about a 10- by 14-inch rectangle. Slurry waste that is scraped into a floor-level filling hopper flows through the flap valve face of the hollow piston on its return stroke. The flow is caused by gravity. Semi-solid waste flow to the piston is aided by gravity via the slanted piston chamber. The piston flap valve closes at the beginning of the next stroke. This forces the waste into and out the discharge pipe. Powered by up to a 15-horsepower electric motor, the mechanical drive pushes waste through the discharge pipe to storage up to 200 feet away. Stroke length is typically 11 to 18 inches. The piston operates at about 25 to 45 strokes per minute, so the potential capacity is about 375 gallons per minute.

This pump is simple to install and maintain; however, it tends to misalign from continuous, high-pressure operation unless correctly installed and anchored. Long straw may plug in the piston valve or the hollow piston.

The horizontal operated piston pump is installed at the bottom of a 6-foot by 12-foot by up to a 10-foot deep basement (see fig. 9–6). An automatically controlled, hydraulic powered solid-faced piston is located in a cylinder at the bottom of a floor level hopper. The piston is about 10 inches in diameter and has a 3-foot stroke. The cylinder fills with semi-solid waste that sinks down through the hopper and is drawn in front

Figure 12–32 Vertical piston plunger waste pump with a pipe anchor (courtesy of Berg Equipment Company)



of the solid piston with the return stroke. On the forward stroke, the waste is pushed out of the cylinder into the discharge pipe past a spring-loaded check valve. On the return stroke, the piston again is pulled completely through the cylinder and past the fill hopper. The spring-loaded check valve prevents waste from flowing back out of the discharge pipe, and the piston suction helps gravity fill the cylinder with waste from the hopper. Operating speed is about 2 to 4 strokes per minute, with a potential pumping capacity of 100 gallons per minute. The relatively slow operation assists the piston return suction (with gravity) to better fill the cylinder with waste.

651.1204 Waste storage equipment

The primary concerns about waste storage include pollution prevention, capacity, cost, durability, nutrient retention, safety, in-use appearance, odors, and expansion. Equipment used with stored waste can be an integral part of the storage (e.g., drive ramp access). The success of equipment use can directly affect how well the storage does its job. Also, some storage equipment use has related alternatives and additional considerations, such as a chopper-agitator pump. Associated equipment, such as loading and unloading access, personnel ladders, covers, and seepage control, is reviewed in this section. Chapters 10 (section 651.1008) and 13 of this handbook give further information on these concerns.

General selection and design information about waste storage is explained in section 651.1003. Additional information about location and management is in sections 651.0702(b), 651.0904(c), and 651.0906. Also see NRCS Conservation Practice Standards, Waste Storage Facility, Code 313, and Waste Treatment Lagoon, Code 359. The ASAE Engineering Practices 393.2, *Manure Storages,* and 403.2, *Design of Anaerobic Lagoons for Animal Waste Management,* include design aspects about storage and related waste equipment (ASAE [l] 1991, ASAE [n] 1993).

(a) Storage interior accessing

A paved ramp (see figs. 8–15, 10–17) is used for clean out and service access to waste storages. A paved ramp may also be appropriate for structural storage facilities. A corner location takes advantage of the existing minimum slope for installation. Ramp thawing or drying and operating visibility are aided if the ramp is located to receive the maximum exposure of the midday sun.

An access ladder is needed for storage structures that have vertical walls. It is used to observe filling, agitating, and pumping operations and to do periodic maintenance. Safety precautions for ladder construction, anchorage, and access by strangers or children are a must. ASAE Standard S412.1, Ladders, Cages, Walkways and Stairs, explains design and installation recommendations (ASAE [o] 1994). Briefly, the recommendations are:

- Space 16-inch wide rungs a maximum of 1 foot apart.
- Allow 7 inches of toe space in front of rungs.
- Use a 27- to 30-inch cage clearance about the ladder.
- Provide work landing platform access.

A waste storage ladder location in plain view by others is preferable. A portable ladder stored away from the waste storage can help deter unauthorized access (see figs. 9–6, 10–18). When in use, the portable ladder should be securely attached to the storage structure to prevent it from falling away and stranding the user. A ladder permanently attached to a storage structure needs to terminate beyond ordinary reach or an entry guard or gate must be used. The attached ladder should terminate at a height of more than 8 feet above the ground. A sunlit location for the ladder helps to quickly dry the ladder and is naturally well lighted.

A ladder permanently located inside a waste storage structure obstructs cleaning. It will also corrode and become unsafe as its deterioration is hidden by waste and poor light. A portable ladder, removed and stored when not in use, is a better alternative.

A stored waste depth marker helps to estimate remaining storage capacity, sludge buildup, and other such problems. The marker should be highly visible. It can be a treated 2 by 4 that is painted white and has footage numbers in red. The marker should be securely located in plain view at the edge of the storage and may need to be periodically cleaned to be visible.

Warning and safety signs and related safety equipment recommended for use with waste management equipment are reviewed in section 651.1208.

Warning: Various gases can be released in volume or otherwise be contained when agitating and pumping wastes in an enclosed space. The displacement of oxygen and/or accumulation of hydrogen sulfide or carbon monoxide is dangerous/fatal. Persons have died after entering an enclosed tanker, storage tank, or waste handling space.

(b) Storage exterior accessing

Waste storage agitation and emptying equipment needs overhead clearance and turning space access (see figs. 9–6, 9–8, 10–12, 10–16, 12–47 to 12–49). An example:

> A vertical wall, belowground, semi-solid/slurry storage structure that is up to about a 60-feet across and 12 feet deep can be agitated and pumped from one pump station using the same centrifugal-chopper pump used for filling the storage. A circular storage shape agitates in less time and encloses more storage capacity than does an equal perimeter length of a rectangle or other storage shape—everything else being equal.

Tables 12–3a and 12–3b can be used for estimating comparative sizes. For example, to store 21,600 cubic feet of waste would require a storage structure that is a 24- by 100- by 10-foot rectangle or a circular unit that is 55 feet across and 10 feet deep.

Additional access space or larger agitation equipment is needed for larger storages, especially for semi-solid waste. An impeller-type agitator (see figs. 10–16, 12–46), a centrifugal-chopper pump, and several agitation pump docks or ramps (see fig. 10–17) are usually needed with large (>100-foot-long) rectangular storage structures.

A straight-line operation for the tractor PTO pump powershaft reduces U-joint wear and fluctuation of speed (see figs. 12–34, 12–46). A level operating area may be needed for gravity lubrication of agitation and pumping equipment.

One of two arrangements is typically used for aboveground storage agitation. One uses a horizontal shaft, centrifugal, chopper-agitator pump mounted on the waste storage tank near the foundation (fig. 12–33, see fig. 9–6). A valve is opened in the storage drainpipe. The pump is then operated to draw waste from the bottom of the storage and pump it up and over the wall and around the top of the storage to agitate the storage contents. This is the only agitation access

Table 12–3a Approximate capacities in cubic feet of rectangular storage (10-foot-long tank)

Width (ft)	Depth (ft)* 4	6	8	10	12
4	120	200	280	360	440
6	180	300	420	540	660
8	240	400	560	720	880
10	300	500	700	900	1,100
12	360	600	840	1,080	1,320
16	480	800	1,120	1,440	1,760
20	600	1,000	1,400	1,800	2,200
24	720	1,200	1,680	2,160	2,640

* Allows 1 foot top freeboard

Table 12–3b Approximate capacities in cubic feet of circular storage (per 1-foot depth)

Diameter (ft)	Depth* (ft^3/ft)
20	314
30	707
40	1,257
50	1,963
60	2,827
70	3,848
80	5,026
90	6,358
100	7,850

* No freeboard

Figure 12–33 Horizontal shaft chopper-agitation pump (courtesy Wieser Concrete Products, Inc.)

unless one or more impeller-agitators are mounted on the inside wall of the storage (see fig. 12–47). In most cases provision is made for adding dilution water near agitators for mixing of semi-solid waste. After agitation the pumpout valve is switched from agitation, and the pump is used to fill a nearby tanker spreader or to supply an irrigator for more liquid slurry.

The second typical aboveground tank unloading arrangement uses a nearby belowground reception tank. In most cases this tank is the same one used for waste collection and for topfilling the storage (fig. 12–34). To agitate or pump, a valve is opened in the aboveground storage drainpipe so waste drains into the reception tank. A vertical shaft, chopper-agitation type pump, operated in the reception tank, pumps waste up over the wall and top of the tank for agitation, or the pump valve is switched to fill a tanker or supply an irrigator. This second arrangement demands closer attention than that required by the first arrangement during agitation or unloading to assure the reception tank does not overflow.

A second safety valve in the storage drain is used to ensure against unload valve failure with any storage that is above an open gravity drain. Such accidental draining protection is needed (see figs. 9–6, 12–34). Local regulations may require a secondary containment dike around an abovegound storage similar to those used for aboveground chemical or petroleum containment. Pumping access, sunlight drying and heating, snow accumulation, and prevailing winds should be considered in locating an agitation station.

Agitation and pumping openings for belowground storage need to be sized, spaced, and located to provide agitation access to tank contents, especially corners. A pump sump (see fig. 12–46) permits complete emptying of stored waste when desired.

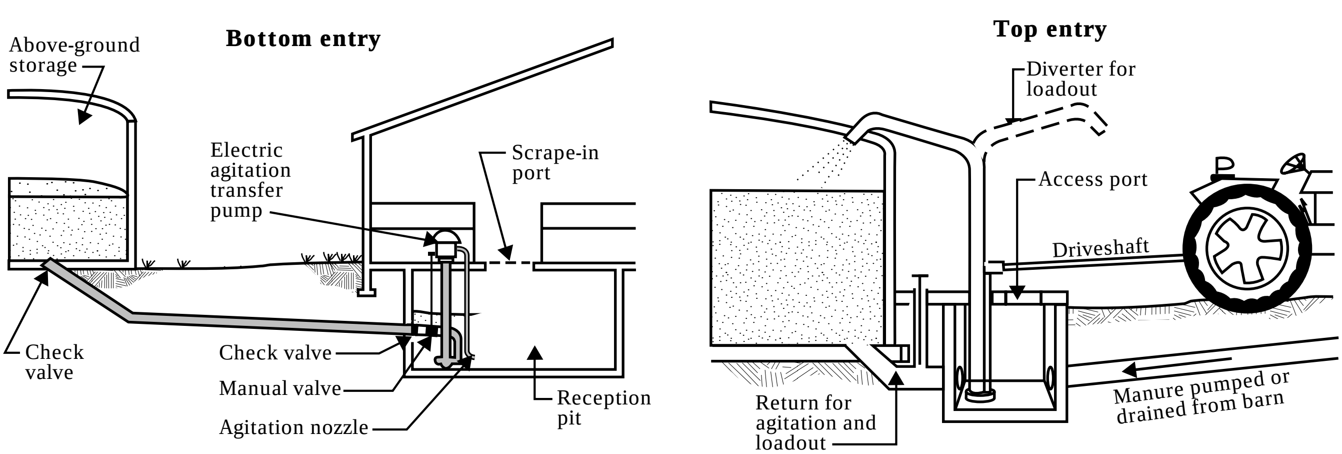
(c) Storage fencing with gates

A fence with locked gate entry is often used with an earthen basin and other open-top waste storage to control access by people and livestock. See NRCS Conservation Practice Standard, Fencing, Code 382, sections 651.1007(a) and 651.1008(c), and figures 8–15, 8–17, and 10–16 for more information. The type of fence should be commensurate with the hazard imposed by the facility.

(d) Covers, drainage, and runoff control

Although the extra cost is questionable in some climates, covering an open-top, aboveground storage reduces evaporation, nutrient loss, plant growth, and odor emission as well as excluding clean water. Study continues on cover equipment design (Huss 1994, Miner 1994, PAMI 1993). A relatively permanent clearspan truss rafter, arch rafter, or similar roof construction is used to support the cover (Switzky 1982). Interior deterioration of construction materials is a consideration. Pressure preservative treated wood,

Figure 12–34 Reception storage or pumping and abovegound storage (MWPS 1985)



exterior grade plywood, corrugated asphalt fiberboard, plastic, fiber glass, and stainless steel are construction alternatives.

Experience indicates that float-supported fabric sheeting, laid onto a holding pond surface and weighted in-place, can be used to collect gas and suppress odor (Melvin & Crammond 1980). Figure 12–35 shows a fabric membrane cover for open-top storage. Although fabric sheeting costs less, the wind can loosen, wear, and blow off a lightweight cover easier than heavier or more permanent covers. Also, accumulated rain and snow on the cover must be accommodated. A cover manufacturer should be consulted on floating plastic cover design and installation (Safley & Lusk 1991).

Barley, oats, durum wheat, and flax straws can be shredded and blown onto a storage's liquid surface using a straw spreader designed for spreading straw along new roadways. Straw is blown directly onto the liquid surface. A 6- to 10-inch-thick layer of good quality barley straw appears to be the most effective material for an unsupported cover. Under a relatively dry climate, one to two applications of this straw will effectively reduce odor for an entire season.

A 1-inch-thick polystyrene float supports a straw cover and keeps it dry for nearly the entire season with excellent odor reduction. The straw/float cover settles to the bottom as the liquid is pumped out. It can be mixed in with the stored slurry waste and field spread.

The Prairie Agricultural Machinery Institute developed a straw cannon that can blow straw out to 180 feet and discharge a 1,500-pound round bale in about 1.5 minutes (Grainews 1994). Straw mixed with polystyrene pellets enclosed in burlap has also been used as storage pond cover in the Pacific Northwest. Odors were greatly reduced, and the cover can be mixed with the pond contents.

The picket dam or vertical slot wall is used to retain solids while permitting water to run off the waste stacked in an uncovered, ground-level, solid or semisolid waste storage structure (fig. 12–36). A picket dam is normally considered a component of the transfer function of a waste management system. It is described here, however, because it is an alternative to roofing a stacking facility.

Figure 12–35 Fabric membrane cover for open top storage (adapted from Safley & Lusk 1991)

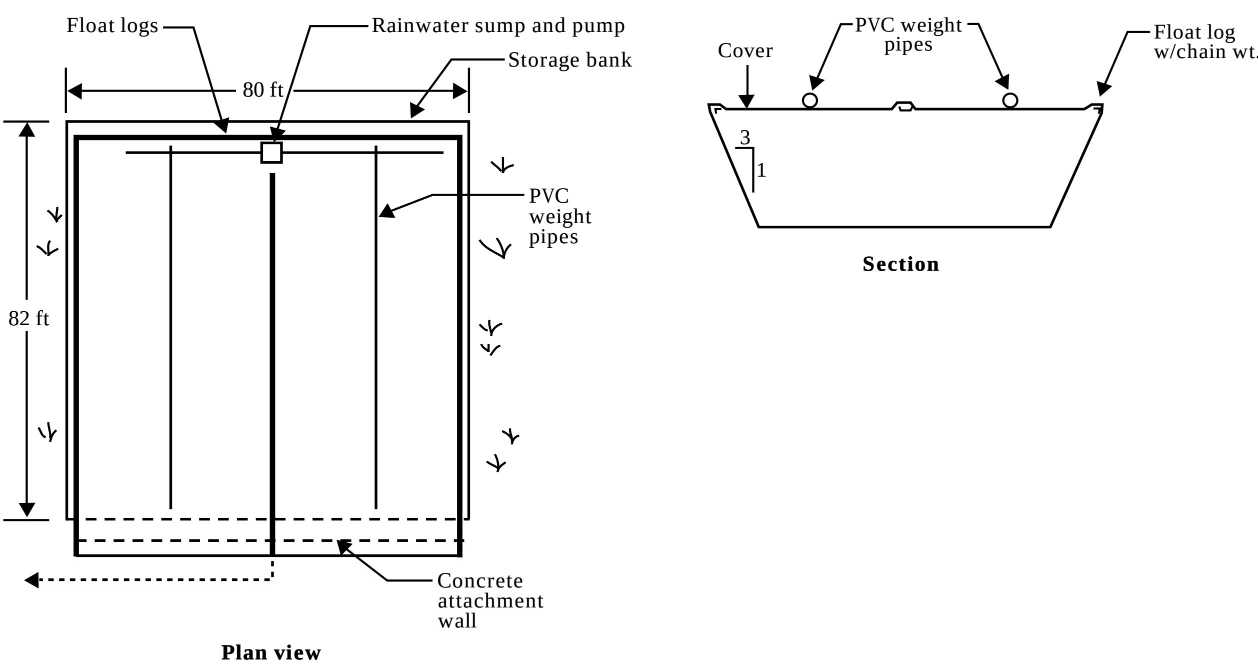


Figure 12–36 Picket dam for opentop storage drainage (MWPS 1985)

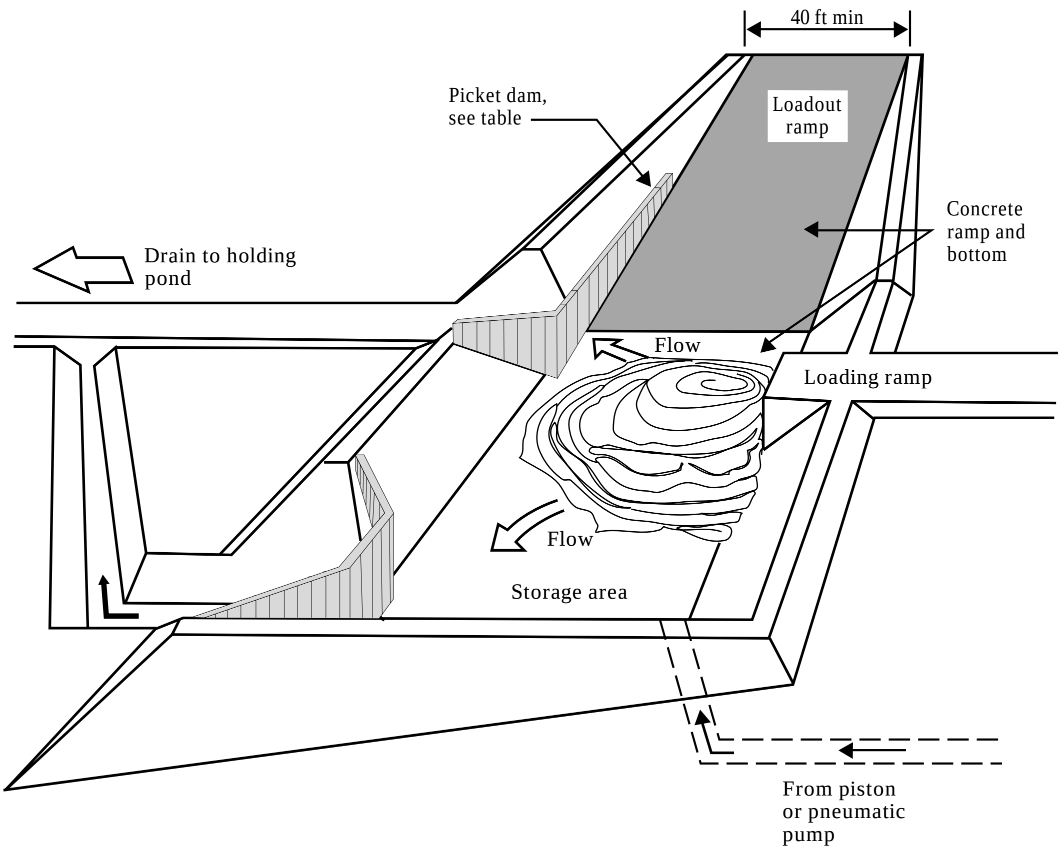
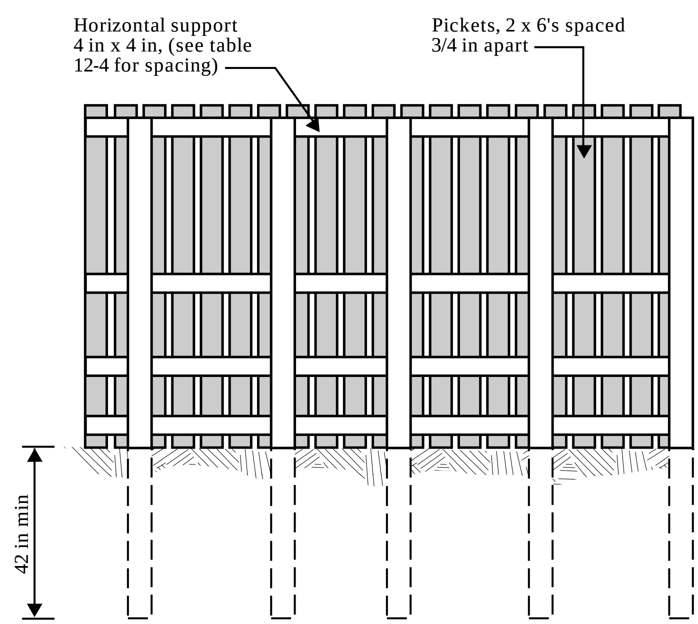


Table 12–4 Picket dam construction (MWPS 1985)*

Posts height (ft)	Posts size (in)	Posts spacing (ft)	Horizontal support distance from picket top (ft)	Horizontal support size (in)	Horizontal support spacing (ft)
0-4	4 x 6	5	0–4	4 x 4	3
5	6 x 6	4	4–6	4 x 4	2.5
6	6 x 8	4	6–8	4 x 4	2
7	8 x 8	3	—	—	—

* Pickets are pressure preservative treated 2 x 6's. Posts and horizontal supports are rough sawn timbers.

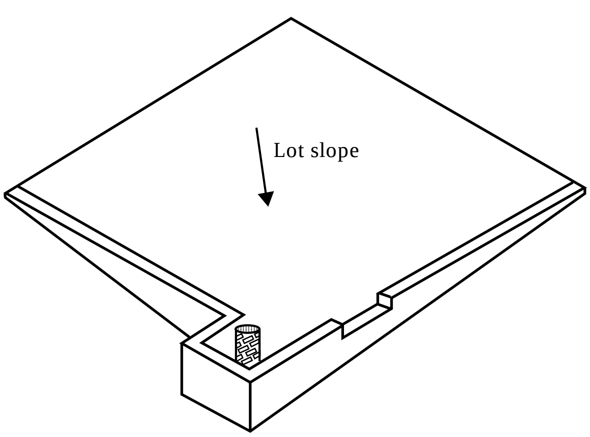


Picket dams are designed to allow runoff from the pile surface at any height within the range allowed by the stacking facility. The dam utilizes vertical slots because they drain and clean better than horizontal slots. The picket dam is located so that a clear drainage path is always away from the face (leading edge) of the pile. Drainage water that exits the dam is collected and transferred to a liquid waste storage facility. Table 12–4 gives construction information for picket dams.

A 6-inch-thick layer of corn cobs on the floor permits seepage from piled semi-solid dairy waste to flow to drains in the concrete floor of a rectangular wooden wall waste storage (Barquest, et. al 1974).

A perforated riser pipe and/or screened drain is used for runoff and piled waste seepage control (fig. 12–37). PVC plastic or steel culvert with 1- by 4-inch slots are typical. The riser pipe diameter and number of slots needs to match the expected flow rate and the required area of expanded metal screen or spaced-plank flow restrictor required. See NRCS Conservation Practice Standard, Structure for Water Control, Code 587, for more information.

Figure 12–37 Perforated pipe runoff seepage outlet (MWPS 1985)



(e) Storage seepage detection and control

Any earthen waste storage has some seepage or leakage (McElroy 1993). The quality of storage construction is a major factor affecting the quantity of seepage. Weak spots or holes in a soil liner, cracks in concrete, poor joints in wood planking or metal sheets, and soil or foundation shifting from frost or moisture changes cause leaks to develop. The small fines in waste seal soil passages around and below the storage; however, this may not suffice as the only sealing mechanism because of long-term unknowns, such as soil movement and repeated surface dryout after emptying. Compacted soil liners are practical unless haul distance is prohibitive. These liners and related expansive clay liners have long been used for pond water storage. However, pond water storage should not be aggressively agitated or regularly emptied to maintain the integrity of the liner. Reinforced concrete or plastic-net soil stabilizer systems used with crushed rock at agitation sites can protect against this problem. Section 651.0703 gives more information on clay liners and soil amendments.

Chapter 7 of this handbook describes liquid movement through soil. Because of ground water quality concerns, a special lining may be required to assure leakage is held to acceptable limits. Different kinds and qualities of liners are used with earthen basin waste storage. NRCS Conservation Practice Standard, Pond Sealing or Lining, Code 521, and ASAE Engineering Practice 340.2, Installation of Flexible Membrane Linings (ASAE [i] 1992) explain criteria for different liners. The criteria include:

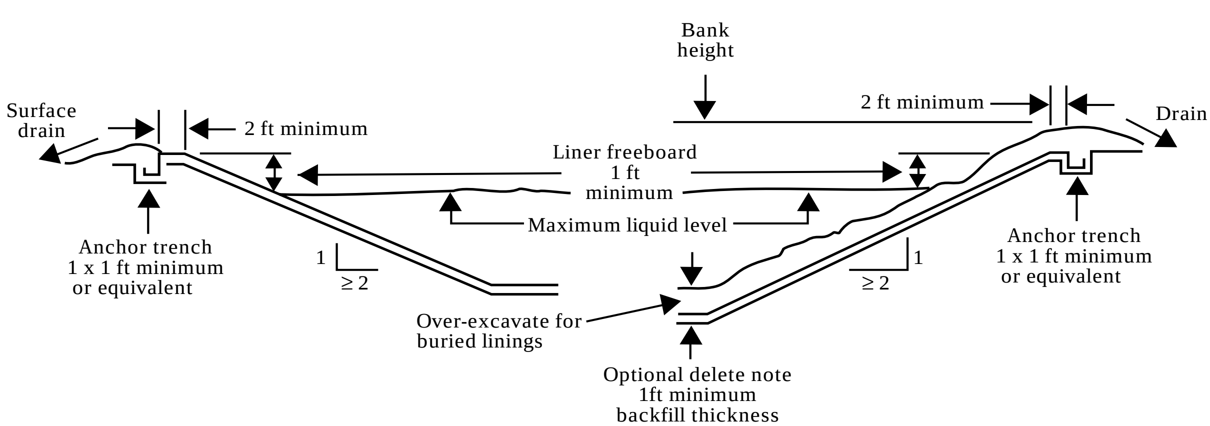
- availability
- size
- cost
- installation requirements
- durability for punctures, tears, ultraviolet light, and rodents and other pests

Safe access for agitation and pumping is needed to prevent fabric liner damage. Higher demands are being made on liners as water quality concerns increase and as liner materials are evaluated and developed for earth basin agricultural waste storage, chemical containment, landfill use, and other applications.

A source of current industry information is the Geotechnical Fabrics Report published by the Industrial Fabrics Association International. Each year, the December issue contains a Specifiers Guide that explains current information about products and services available. Figure 12–38 shows a membrane liner.

The Natural Resources Conservation Service has completed a study about seepage from earthen storage ponds and waste treatment lagoons (Moffitt 1993). A part of the study was to determine what are seepage conditions, and another part was to measure the extent of seepage. One promising technique is the electromagnetic terrain conductivity meter (EM-34) that senses the added electrical conductivity resulting from increase in ion concentrations that may be caused by waste impoundment seepage. The EM measurement information can be used along with that from monitoring wells and soil borings. The Geonics EM 39TM and companion tool, the natural gamma probe, measure the incremental conductivity in a borehole. They can indicate if the conductivity anomalies are in materials that are likely to transmit fluids.

Figure 12–38 Membrane liner installation for earthen basin (courtesy Hoechst Celanese Corp.)



651.1205 Waste treatment equipment

Treatment of waste is in sections 651.0904(d), 651.1004, and with the different waste management systems in section 651.0906. Treatment changes the makeup of waste into a more usable, stable product, or it mechanically enhances its natural biological breakdown. Treatment equipment includes that for grinding/shredding, agitation/mixing, aeration, separation, drying, dehydration, incineration, and rendering.

(a) Size reduction

Cutting, shredding, crushing, or grinding reduces the bulk and increases the flowability of relatively dry (>60% dry material) material, such as leaves, roughage, brush, paper, cardboard, cans, and bottles. Waste type, amount of use, power need, investment, noise, dust, and maintenance must be considered in selecting grinder and shredder equipment.

Cutting equipment pushes thin, sharp knives through a usually moist material to reduce its size into uniform pieces. Cutting, as such, results in minimum deformation and rupture of the reduced particles. Equipment with very sharp cutter blades and close tolerances is used with fruit and vegetable processing. Some chipper equipment uses heavy knives mounted on a high-speed cylinder that rotates inside a housing. The high-speed cutter/grinder for processing slurry waste also uses this type equipment (fig. 12–39). Unless the blades and cutter bar edges are intensively maintained, cutting equipment performance is more a shearing/ tearing action. If this happens, a crushing as well as cutting action occurs, which increases power need, slows throughput, and produces a ragged product.

Shearing is generally used to reduce the size of loose, bulky, tough fibrous material. Brush and some straw chopper equipment usually employs more shearing than cutting to reduce material size (see fig. 12–31). A belt type shear shredder (fig. 12–40) uses a cleated belt operating in a hopper to force material against stationary knives. Material loaded into a receiver hopper feeds a conveyor that in turn drops it onto the cleated belt where it undergoes a continuous raking action to shred the load. Adjustable sweep fingers force oversized pieces back for further shredding while hard stones, metal, and glass are discharged through a trash chute. Engine-powered stationary or tow models are available. Power needs range from 7.5 to 500 horsepower with capacity from 5 to 50 tons per hour, depending on raw product moisture, density, and fineness.

Figure 12–39 Cutter-shredder for slurry waste (courtesy Hydro Engineering, Inc.)

The rotary shear shredder uses two counter-rotating shafts with overlapping hooked cutter discs (fig. 12–41). Cutters draw material down toward shafts at the base of a hopper. The cutters slice the chunks into small pieces until they pass through the spaces between the cutter discs. This process has been adapted to some wood chipper equipment. The piece size depends on cutter size and spacing.

As semi-solid waste is forced through relatively close tolerances, it is slurried by chopper-agitation pump impeller (propeller) action during agitation and pumping. See section 651.1206(b)(1)(ii). Stationary knives are included on some models to assist rotating exposed cutter blades to cut twine and other tough fibers (fig. 12–42). The rotating blades also crush or break apart semi-solid chunks as they are drawn into the pump impeller. Unless the impeller is plugged, the crushed material is then slurried. A common operator complaint is that twine and plastic wind onto the rotating cutter. Small stones, metal, or other foreign material quickly dulls cutting edges, so high maintenance is needed for satisfactory shearing performance.

The versatile hammermill grinder uses 20 to 50 short, free-swinging, hardened steel strap-irons mounted on a high-speed rotating shaft to hammer or crush solids through a surrounding, close-fitting perforated screen (fig. 12–43). Readily interchangeable screens, each with different-sized openings, are used to produce relatively uniform coarse to fine grinds. Fine grinding needs high power and a slow grinding rate as does higher moisture content (>15%) material. Different models of portable and stationary hammermills are available. These can require 5 to 550 horsepower and can coarse-grind up to 50 tons per hour of dry (≤15% moisture) waste.

Hammermill grinding increases the temperature of the material ground about 10 degrees Fahrenheit. It is increased more with fine grinding and higher moisture content materials. This increased temperature must be considered when the processed waste is stored. Compared to the cutter and shredder treatment, power and maintenance needs are higher for a hammermill grinder, especially if stones or metal pieces are in the waste.

Figure 12–40 Belt-type shear shredder (Rynk 1992)

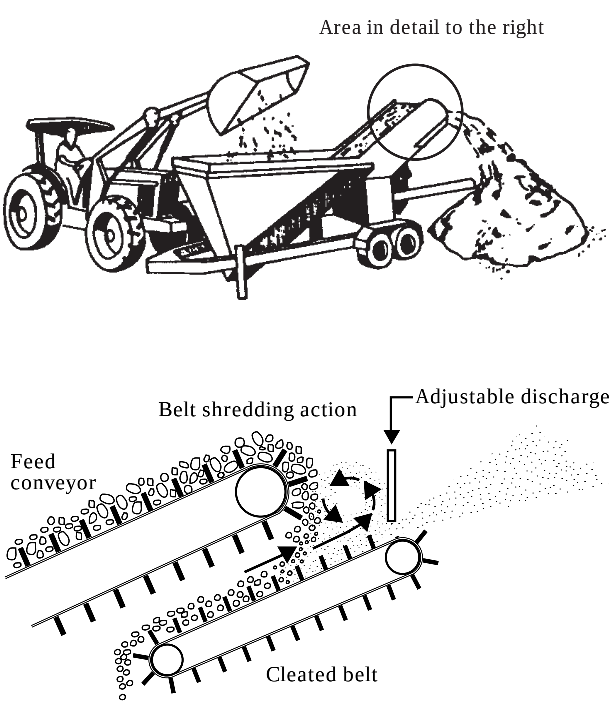
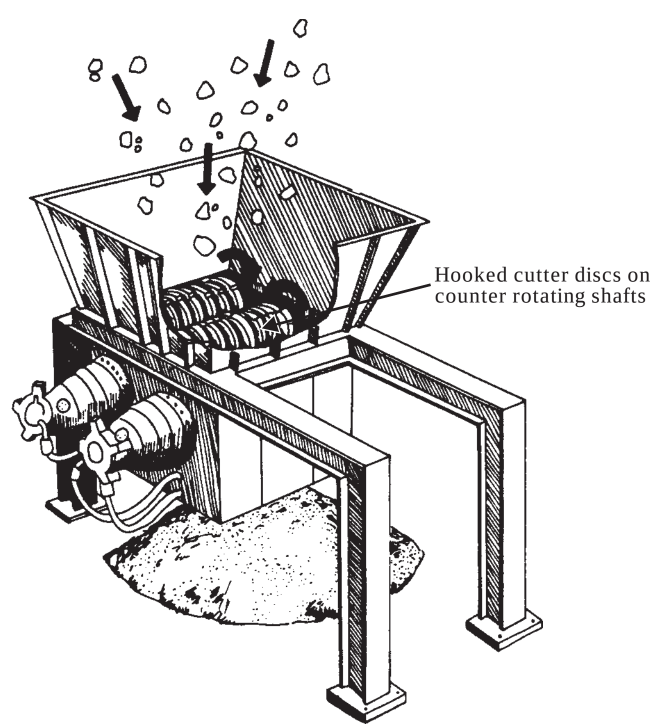


Figure 12–41 Rotary shear shredder (Rynk 1992)



Widely used on farms to grind livestock feed, the portable grinder-mixer usually employs a 50- to 100-horsepower PTO-powered hammermill in conjunction with a vertical auger type tank mixer. Larger, much heavier constructed models of this versatile equipment have been developed for high-rate processing of solid waste.

The tub-grinder (fig. 12–44) incorporates a hammermill type grinder in the floor of the slowly rotating hopper or tub. As the tub rotates, it carries around the material dropped into it. This material eventually feeds into the hammermill, is ground, and falls into a conveyor below. Tub grinder models are available that require about 70 to 525 horsepower. The smaller models can be PTO-driven, and larger units are industrial diesel-engine powered. Different models employ an intake screen, feeder/hopper, crusher, and various conveyors for separated materials. This equipment can all be on one moveable chassis.

Figure 12–42 Cutter blade on chopper-agitator pump (courtesy Clay Equipment Corp.)

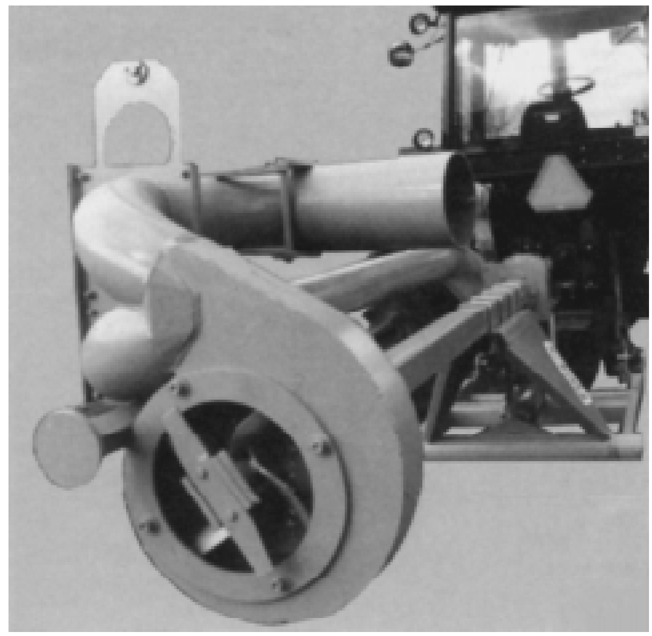


Figure 12–43 High capacity hammermill grinder (Rynk 1992)

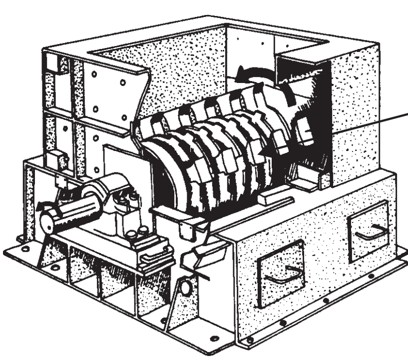
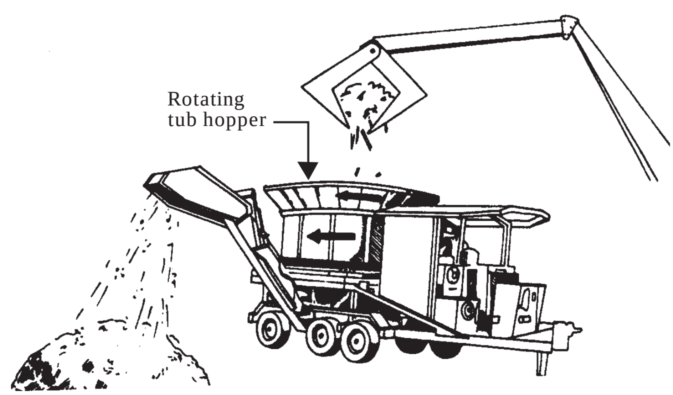


Figure 12–44 Large capacity engine powered tub grinder (Rynk 1992)



(b) Agitators, stirrers, mixers

Agricultural wastes usually contain materials of different densities. These tend to separate out during handling, storage, and use, especially with the more slurry waste. Soil and other dense materials settle over time while straw, feathers, and other bulky materials float. Agitation equipment is used to remix the separated materials together for complete product handling, improved aeration, and decomposition. Different agitation equipment is available. Selection depends on the waste moisture content, desired agitation capacity, investment, available power, and the waste use.

(1) Semi-solid and slurry waste agitators

Although useful with liquid waste, vacuum tanker agitation usually is insufficient with semi-solid waste, especially where there is a surface crust. See section 651.1207(a). Chopper-agitator PTO-driven pumps are designed to agitate as well as pump semi-solid waste (fig. 12–45, see figs. 9–8, 10–16). See section 651.1206(b)(ii). Such alternative equipment use helps reduce the total investment. This one-unit operation, however, may slow down loadout and spreading depending on how agitation progresses. During agitation a diverter valve on the pump outlet is manually set to return the pumped material back into stored waste via a hand operated nozzle that has vertical and horizontal adjustments. To agitate settled solids, a vertical shaft drive chopper-agitator pump (fig. 12–45) usually recirculates and discharges through a nozzle below the stored waste surface. Some models have a second, higher discharge nozzle to agitate a surface crust.

Agitation nozzle location and adjustments can be critical, especially for agitating into storage corners. Most 50- to 80-horsepower chopper-agitator pumps can agitate out about 40 feet depending on nozzle design, pump wear, waste consistency, and storage shape. Several moves generally are used to agitate a large rectangular storage. See section 651.1204(b). Agitation and pumping docks are needed with large earthen basin storage to be agitated with a vertical shaft drive chopper-agitator pump. Appendix 12B, USDA Plan 6381, explains concrete or wood dock construction. (**Note:** Mention of plans is only for planning information purposes. The Natural Resources Conservation Service approval procedures require that waste storage structures meet practice standards that include carefully engineered design analysis for specific site conditions.)

For faster, more effective agitation over a larger area, the open impeller (propeller) agitator has evolved from the vertical shaft drive chopper-agitator pump. Electric motor-powered models that are up to 12 feet long with 15 to 25 horsepower are made for use in vertical wall storages (fig. 12–46) or float-mounted for moving over and agitating earthen basin type storages (fig. 12–47). Models more than 40 feet long (fig. 12–48, see fig. 10–16) can be PTO- or hydraulic-motor powered and 3-point hitch, 2- or 4-wheel trailer mounted. All-purpose models of impeller type agitators have a chopper-agitation pump, separate agitation nozzle, and tanker fill pipe (see fig. 10–16).

A hydraulic shifted gearbox is used to select the desired agitation or pumping mode. Most impellers are 3 steel blades and are from 1 to 2 feet in diameter. Depending on speed, the power needs range from about 35 horsepower for the 1-foot model to about 150 horsepower for the 2-foot, 0.25-inch-thick steel, impeller agitators. Impeller size, pitch, and blade number are based on manufacturer experiences.

Agitator location and operation depend on the location and relative amounts of settled and floating materials in the waste. With earthen waste storage ponds, solids generally settle near the storage inlet. With vertical wall storage, they tend to build up in the corners.

Opinions vary on agitation techniques, and little research information is available for different storage shapes, sizes, and depths. The corners of rectangular earthen basin storage are often agitated first to break up the surface crust and get the storage contents moving. After the waste has been moved for several hours and given the available power, durable equipment, and added mix water, stored semi-solid waste becomes slurried.

Agitated semi-solid and slurry wastes, if allowed to resettle and separate after agitation, are more difficult to reagitate because of more fine material. In some cases where solids have settled in a semi-solid or slurry waste storage, the storage structure may require dredge agitation equipment or manual cleaning. A large dragline dredge is the most effective way to clean out a large open storage. Small (30 to over 100 horsepower) floater type agitation dredges are available (fig. 12–49).

Figure 12–45 Vertical shaft PTO-powered chopper-agitator pump (courtesy Whatcom Mfg.) Source: Canada Farm Building Plans Service (1993)

Figure 12–46 Chopper-agitator pump and open-impeller agitator (courtesy J. Houle & Fils, Inc.)

Figure 12–47 Float-mounted impeller agitator (courtesy US Farm Systems)

Figure 12–48 Open impeller with long shaft agitators (courtesy Whatcom Mfg.)

Skilled operation is needed to control the floating agitator location and to accomplish thorough agitation of stored material. Control of depth and forward movement is important to loosen and agitate settled solids without disturbing the storage liner.

Settled, packed solids in relatively small semi-solid storages can be loosened with correct use of chemical and biological additives and a high volume or pressure of water (>1,000 psi).

(2) Solid waste agitators

Stacked or piled waste settles and shrinks as it decomposes and dries. Compost methods use agitation equipment to mix dry and wet materials and provide airways (aeration) that aid decomposition. For more information on composting, see section 651.1004(f).

A tractor front-end loader or skidsteer loader is simplest to use for agitating (scoop-lift-move-dump) the piled compost. See section 651.1203(d). Depending on the site conditions and arrangement, operator expertise, and loader bucket size, the windrowed compost turning rates for this technique range from 20 to more than 70 cubic yards per hour.

Agitation quality is affected by the mix of added materials, unevenly wet compost, and strong wind gusts. To aid in uniform mixing, a box spreader, such as that described in section 651.1207(a); potato digger; rock picker; or related elevator laydown type of equipment can be adapted for agitating windrowed compost. Low profile cruster equipment has been developed to pick up and re-lay (or load) solid bedding litter in large poultry barns (fig. 12–50). This equipment needs 18 to 60 horsepower, depending on the loading rate and litter quality. Loaded litter can be stacked or field spread.

Figure 12–49 Floating dredge agitator (courtesy Crisafulli Pump Company)

Heavy duty agitation equipment has been developed for agitating windrowed compost to reduce labor, increase output, and provide a uniform mix (fig. 12–51). Tractor tow, PTO-powered, and self-propelled models are available. These windrow turners employ varied agitator designs. They include:

- A large diameter (about 3-ft) auger to move the windrow sideways.
- A rotating drum that has spike flails attached in a spiral. The spiral goes under the windrow, lifts it up, and re-lays it.
- A wide, high elevating belt that works the same as the rotating drum.

The auger type is simplest, but needs relatively high power. Rotary drum types are made in different models that require 65 to 440 horsepower and have a capacity rated from 800 to 4,000 tons per hour. The wide, high elevating belt agitators require from 65 to 125 horsepower and are rated from 2,000 to 3,000 tons per hour. The elevating belt models generally are towed by a tractor and turn or agitate half the windrow in a single pass. This requires tractor drive space between windrows that, in turn, need drainage and maintenance.

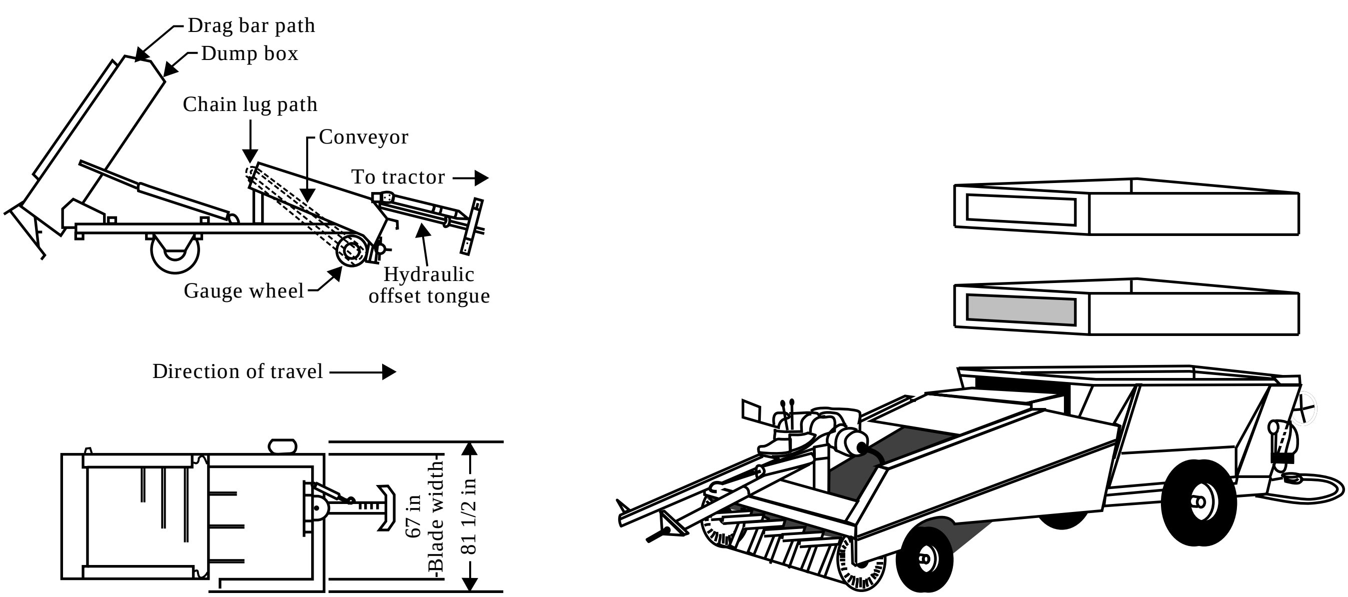
Mixing additional materials with wastes is another solid waste handling agitation procedure. Either continuous flow or batch mixing equipment is available. The following factors should be considered in selecting the equipment to use:

- Capacity
- Cost
- Material moisture content
- Mixing quality
- Power
- Dust
- Noise

An ordinary U-trough auger conveyor operated at an incline can be used as a continuous-flow solids mixer. The materials to be mixed are fed in at the low end of the auger. The conveyed material rolls and mixes when conveyed up an incline of 25 to 45 degrees. The length of conveyor required depends on the materials and mix quality.

The pug mill is a large capacity, continuous-flow heavy duty mixer used in sludge composting (fig. 12–52). The mill is generally operated at a stationary site, so materials to be mixed are conveyed over to and metered

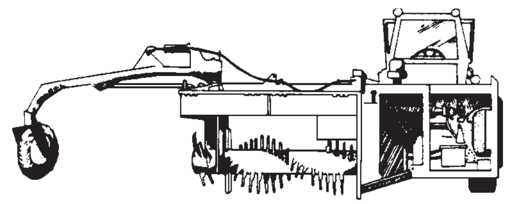
Figure 12–50 Elevator scraper for solid waste agitation and hauling (courtesy Gregory Mfg. Company)



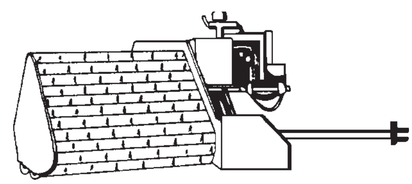
into the mill. Materials are mixed as they pass through the counter-rotating paddles. Different-sized pug mills are available. The throughput rates range from 10 to more than 500 tons per hour with power needs from 10 to more than 50 horsepower, depending on material quality.

Different batch mixer designs for mixing foodstuffs and fertilizers have been adapted to agitate solid waste, such as compost, sludge, straw, and paper. These mixers are mounted on a trailer or truck, and they use electric, PTO, or engine power. Batch mixers that use rotating horizontal-suspended augers that are 1 to 3 feet in diameter (fig. 12–53) may cost less than reel, paddle, or ribbon mixers, but they have higher power and operating time needs. Power needs range from 10 to more than 50 horsepower for reel mixers rated at 5 to 30 tons per hour. The rotating drum cement mixer has been adapted for solids mixing.

Figure 12–51 Windrowed compost agitators/turners (Rynk 1992)



Push-type, self-powered (diesel engine) rotary drum with flails



Tractor-towed, self-powered, elevating-face conveyor

Figure 12–52 Pug mill mixer for dense, solid waste (Rynk 1992)

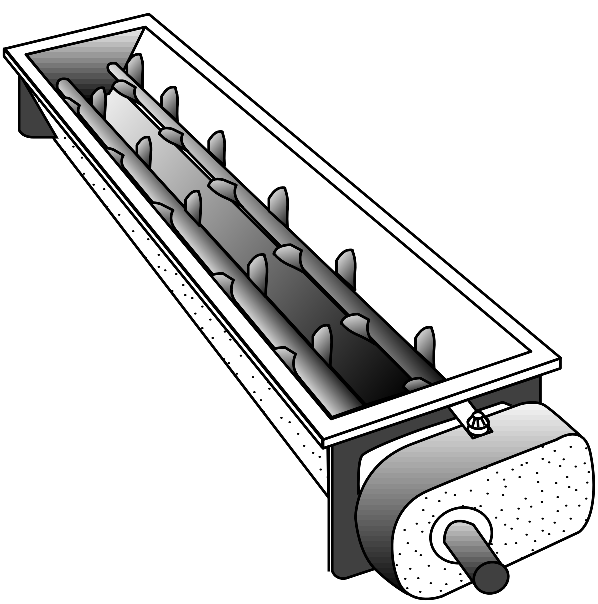
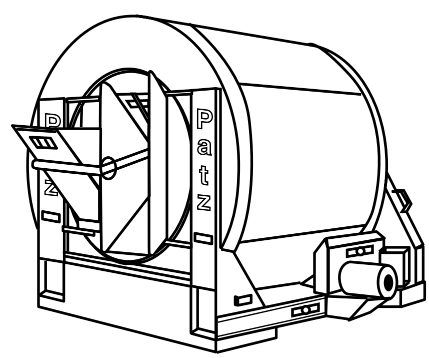
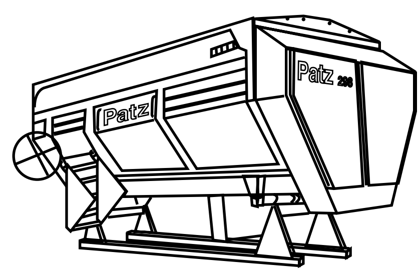


Figure 12–53 Batch mixers for solids mixing (courtesy Patz Sales, Inc.)



Tumble mixers



Stationary auger mixers

(c) Aerators

The continual forcing or mixing of air with stored waste affects its odor and temperature control as well as the decomposition rate. Equipment has been developed for aeration of solid, semi-solid, slurry, and liquid wastes. While the use of agitator equipment with stored waste also aerates, the aeration result is non-uniform and relatively temporary.

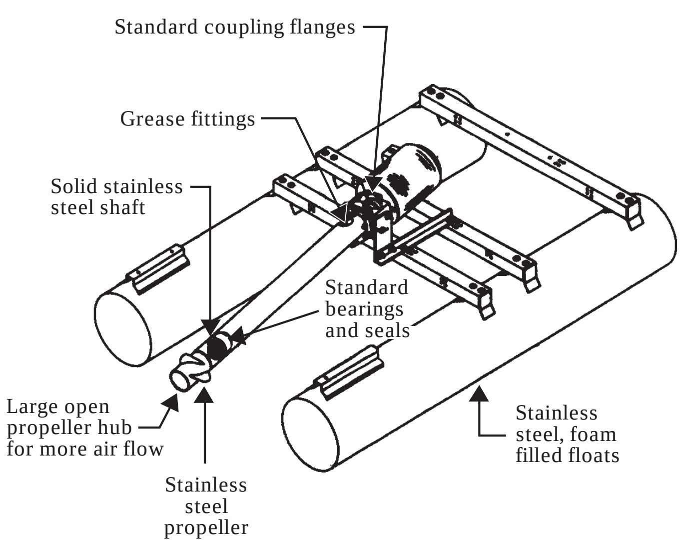
(1) Slurry and liquid waste aerators

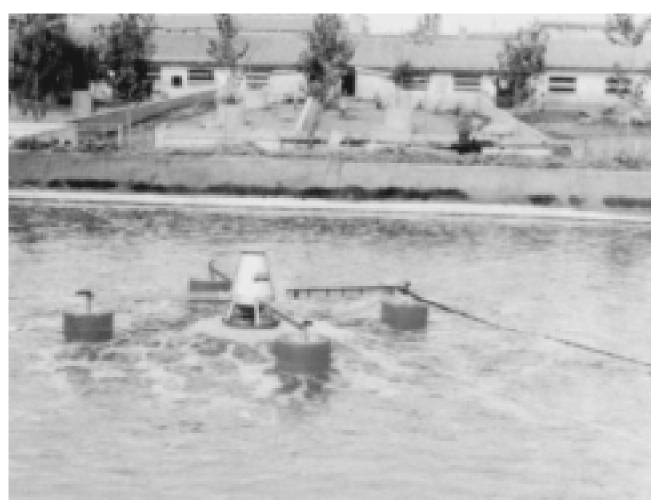
Mechanical aeration of liquid lagoon waste is explained in section 651.1004(c). Beside this kind of development for agricultural waste aeration, the aquaculture industry has varied equipment and experience with liquid aerators used with commercial fish farming as do wildlife agencies working with pond and lake aeration.

Mechanically aerated lagoons combine the odor control advantage of aerobic lagoons with the smaller size requirements of anaerobic lagoons. They are most often used to control odors in sensitive locations or for nitrogen removal where land disposal areas are severely limited. However, use of floating surface aerators to provide oxygen is much more expensive than anaerobic lagoon operation, both in initial cost and maintenance and operating expense. For floating aerators the minimum aeration requirement for odor control at the lagoon surface is about 1 horsepower per 750 to 1,000 square feet of surface area. Use of aeration equipment for complete mixing of the lagoon liquid is normally considered uneconomical and unnecessary except where a high level of odor control is required. An engineer needs to plan equipment needs based on the chemical oxygen demand and the fraction of total nitrogen that can be converted to nitrate by aeration for the design situation.

Floating liquid surface pump aerators use an impeller (propeller) directly connected to an electric motor. This impeller helps pump the liquid upward where it mixes with air and falls back down into storage (fig. 12–54). The pumping and aeration depth is generally less than 4 feet, and the affected area ranges to a 50-foot diameter, depending on the design and power available. Power needs, pump plugging, splash control, and freezing are problems. Liquid and air mixing is usually more effective with the pumped water than with the diffused-air type floating aerator that forces air into the liquid (fig. 12–55). Air is compressible, and liquid is not, so the lighter weight air has more tendency than pumped liquid to take a path of least resistance.

Figure 12–54 Floating aerators for liquid waste aeration (courtesy Aeromix Systems Inc. and AgriBusiness International, Inc.)





One or more floating aerators are typically strategically spaced over an open lagoon storage surface so that each unit aerates a certain area of designed capacity (fig. 12–54). These aerators are floated over to the desired location for operation and secured to the storage edge with anchor cables. The anchor cables can support 240-volt power wires; however, the support distance and wire size must be considered.

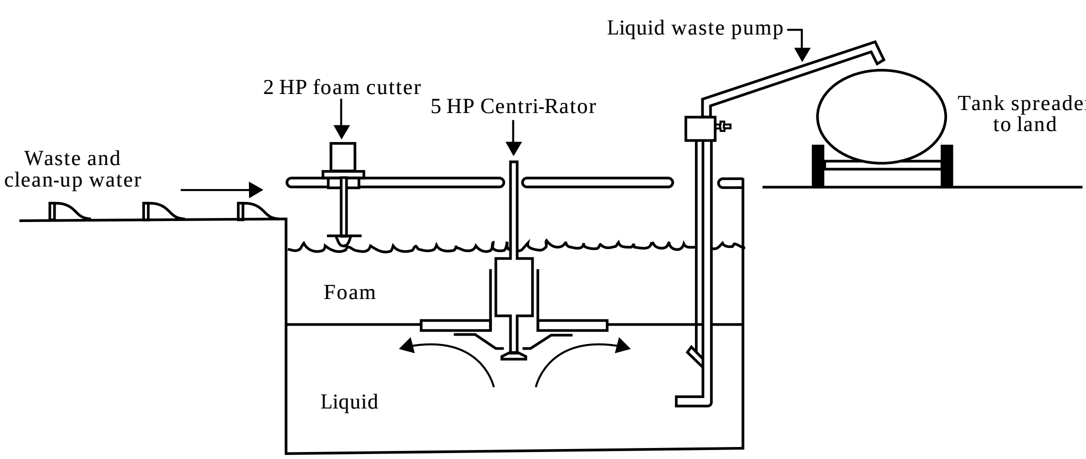
Diffused aerators that force air into liquid and slurry waste have varied designs (fig. 12–55). They include one that uses a submerged impeller that mixes air supplied to it via an intake tube with the surrounding stored waste. Another design uses an air blower located at the storage surface to force air down a duct or distributor arrangement into the stored liquid below. Most diffused aerators have relatively small capacity and horsepower; however, one manufacturer uses a supercharger blower to force air to the directed output of a submerged impeller. Several models are available with up to 10.5 horsepower; however, uniform mixing of air with the liquid and plugging of the diffuser hole are problems.

The Delaval Centri-Rator*tm (fig. 12–55) is a stationary diffused air type aerator used over the past 20 years for waste treatment. This design has the aerator mounted in the center of a circular waste holding tank. The regular inflow-outflow of waste is constantly agitated and aerated. A surface foam cutter or liquid spray is employed to break up surface foam that develops from intermittent waste loadings. After some 24 hours of aeration, the liquid waste flows on to another aerated tank or storage for continued decomposition (Rupp 1992). The flow deflector plate assists with more thorough mixing of air with liquid. Cost, continual power needs, regular maintenance, and freezing are considerations.

The rotating oxidation (aeration) wheel operating in a 3-foot deep oval racetrack-shaped concrete ditch was developed for liquid domestic waste treatment in the Netherlands (see fig. 10–29) (Martin et al. 1978). This oxidation wheel was adapted to livestock production systems around 1970 to provide a means of onsite waste treatment. Agricultural engineers at the University of Illinois studied its use with swine waste, and Purdue University studied its use for cattle waste treatment (Jones et al. 1972). University of Minnesota engineers researched oxidation wheel waste treatment for confined beef cattle over a slat floor in cold weather (Moore et al. 1969).

Varied designs have been used for oxidation wheels. A typical design is a series of many closely spaced paddles. The paddle lengths used vary from 0.5 to 1 foot long. They are securely fastened to a shaft about 4 feet long that is rotated at several hundred rotations

Figure 12–55 Diffused-air liquid and slurry aerator



12 ft deep by 20 ft diameter tank with concrete lid

per minute and requires about 20 horsepower (fig. 12–56). The vigorous action of the paddles moving through the liquid surface causes the air and liquid to mix. Correct design, installation, and operation are critical. Costs, uniform waste addition, continuous power need, bearing wear, foaming, solids build-up, and regular liquid overflow handling problems caused oxidation wheel use to disappear for agricultural waste treatment.

(2) Solid waste aerators

Unlike agitated pile solid waste composting, static pile composting employs natural or forced aeration to control pile temperature and aid aerobic decomposition. Figure 12–57 shows guidelines for perforated duct placement using passive or natural air movement.

For uniform airflow, the key is to establish good structure and pile porosity. Air naturally tends to flow into the open-ended pipes, that are 4 inches in diameter, and out through the 0.5-inch holes on 1-foot

Figure 12–57 Perforated duct placement for gravity aeration (Rynk 1992)

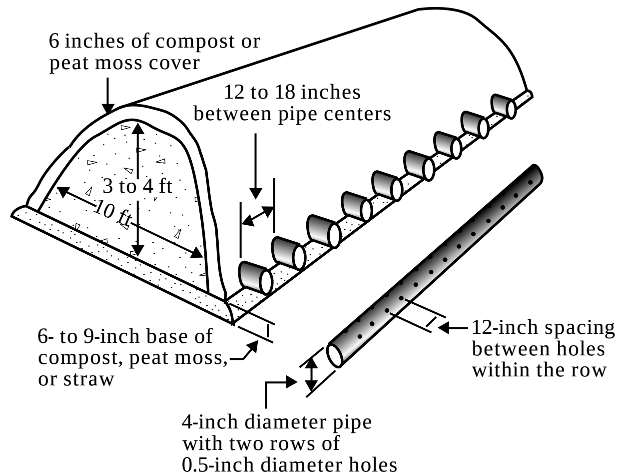
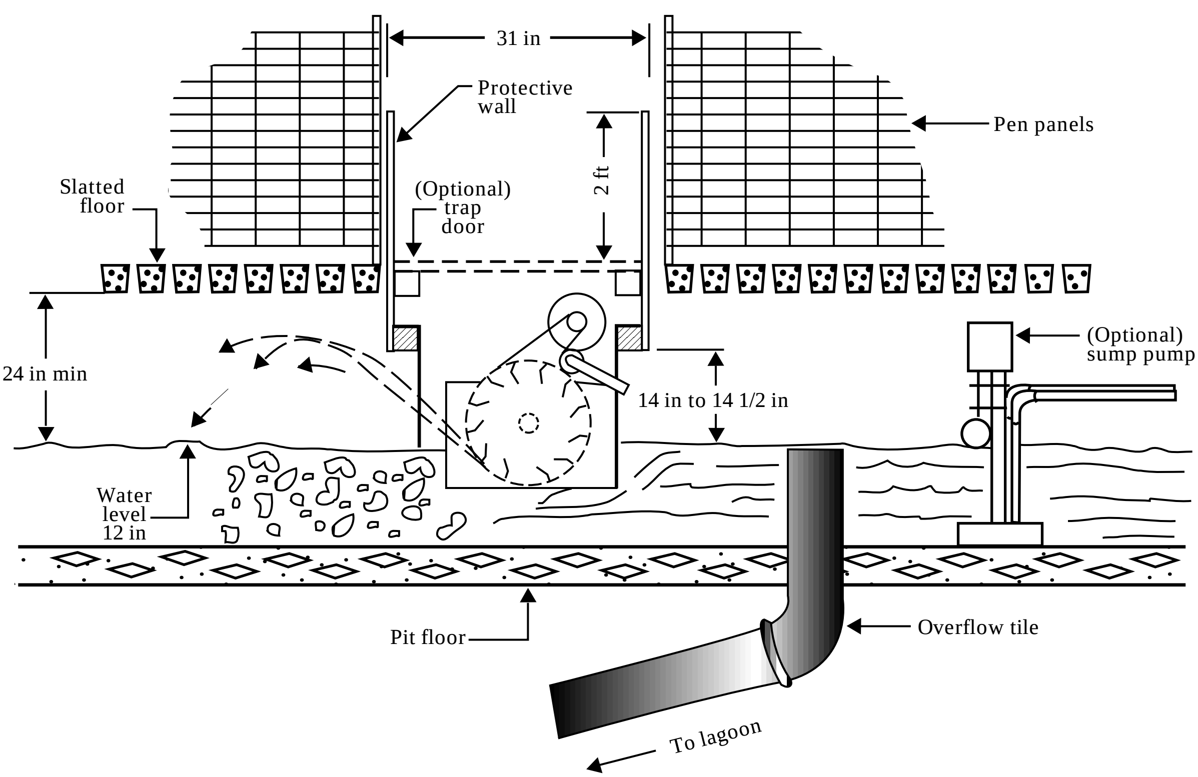


Figure 12–56 Oxidation wheel liquid waste aerator



centers and then through the pile. This movement is because of the chimney effect of warmed air moving upward out of the pile. A peat moss or similar covering insulates the pile, discourages flies, and aids moisture and odor retention. Ordinary septic or leaching field plastic pipe is used for the air ducts. The pipe holes are placed facing downward to avoid their plugging. The pipes are pulled out when composting is complete. Wind causes dust in an exposed area; however, it assists natural aeration.

Mechanical aeration of a static pile or in-vessel composting system employs an electric motor powered forced air blower that is temperature controlled. The system design depends on storage shape, airflow quantity, and distribution (see fig. 10–31). Approximate design requirements for temperate climate conditions are shown in table 12–5. Application of these specifications becomes complicated and is explained more in the On-Farm Composting Handbook (Rynk 1992).

Airflow static pressure for an approximately 6-foot-deep pile of roughage compost can range from 2 to more than 4 inches of water, depending on the compost mix, moisture content, and airflow (Keener et al. 1993). Fresh compost requires a controlled flow of air to maintain a pile temperature at about 140 degrees Fahrenheit. In practice the blower speed or cycle and the airflow through the duct system must be adjusted, or the pile size must vary to suit compost temperature conditions. Because pipe selection and airflow distribution arrangement affect operation performance and costs, especially for a large compost operation, these decisions are critical to the success of the operation, and special design planning is recommended.

Table 12–5 Blower and pipe sizing for pile aeration (Rynk 1992)

Component	Time-based control	Temperature-based control (130 to 140 °F)
Blower horsepower	0.33 to 0.5	3 to 5
Airflow ft^3/s per dry ton of waste	10 (continuous operation)	- - -
	25 (1/3 on 2/3 off)	100
Pipe diameter (in)	4	6 to 8
Maximum pipe length (ft)	75	50

Blower selection depends on the airflow rate at a needed static pressure, the tolerable noise level, and power availability. Airflow is measured in cubic feet per minute, and static pressure in inches of water column or inches of water. Blower static pressure is affected by:

- Depth of the compost—increases linearly for each added foot of depth.
- Quantity of the airflow (cubic feet per minute per cubic foot of compost)—the static pressure triples when airflow doubles.
- Quality of the compost—restricted by wet, heavy material, the air moves easily through fluffy, dry, uniform material.
- Airflow ducts—sharp corners and too small ducts restrict airflow, especially at high rates.

Correct blower selection provides the proper airflow amount for the quantity to be aerated. To determine the airflow rate, divide the cubic feet of material by the cubic feet to be aerated.

Electric motor power is nearly exclusively used for blower power with many types of control commonly available. The controls include: on-off, percentage timer, time-clock, thermostat, and variable speed. Motor horsepower is a poor way to compare blowers because the blower performance is determined by its design, and the blower horsepower is determined by airflow, static pressure, and blower efficiency. Horsepower needs vary at different combinations of airflow and static pressure, and a maximum horsepower input occurs at a specific combination thereof. The blower motor needs to operate continuously at this maximum requirement for horsepower. Manufacturers can supply this information for their different models.

The axial flow and centrifugal blowers are commonly used for forcing air through materials at relatively high static pressures (fig. 12–58). A wide selection of either blower type is available ranging from about 200 to over 5,000 cubic feet per minute capacity and at relatively high static pressures. An undersize blower will not control compost temperature. Too large a blower results in too much cooling and erratic compost decomposition. A high airflow rate at a higher static pressure generally is needed at the start of composting. Airflow needs reduce as decomposition and compost agitation occur, so a means of reducing airflow is needed. Total airflow can be reduced by careful use of intermittent blower operation, a slower speed, a smaller blower, or by diverting or blocking some airflow. The axial flow blower generally costs less than the centrifugal blower, is less noisy, and is better suited to static pressures below 3 inches.

Equipment for aerating the separated solids from dairy waste has been in use since 1990 at the USDA Dairy Forage Research Farm in Prairie du Sac, Wisconsin (fig. 12–59). Separated solids (about 20% dry matter) are conveyed from the solids/liquid separator and leveled to a depth of 6 feet in a 10- by 12-foot aeration bin. The plastic aeration tubes, which are 5 inches in diameter and have 0.5-inch holes about 1.5 feet apart, are laid on spacings in the concrete floor at 3-foot intervals. One bin is filled, during a 3-week period, while another bin is aerated. A third bin, previously aerated, supplies periodic bedding needs for stalls.

Recommended improvements for this equipment include (Straub 1993):

- Some means to prevent plugging of the air-outlet holes in the floor when driven over by a front-end loader to unload.
- A way to plug and unplug aeration holes during filling until they are covered with separated material.
- A way to assure that the first material in the bin is the first out.

Different models of relatively high investment in-vessel composters have equipment adapted to these problems (see fig. 10–32).

(d) Separators

Agricultural wastes include various materials mixed together. Even a rough separation (scalping) of these materials can aid handling, processing, and agricultural waste product end-use. Various screens are used for separating most types and sizes of relatively large solids. Filtering equipment is more useful for separating fines. Criteria to consider before adding separator equipment to a waste management system include:

- Waste moisture content—Some separators require a dilute slurry, so additional water may be needed, while the solids separated may need to be dried.
- Separator opening size—12- to 30-mesh screens are common for solids and liquid stationary screens. About half that size is needed for vibrated screens. Small openings remove solids, but they also slow the system throughput.
- Throughput rate or capacity—This determines the separator size needed for the system. Some plugging and slowdown are inevitable.
- Maintenance—The equipment must be maintained, and mechanical conveyors, pumps, and separators need power with belt or chain drives.
- Costs for peripheral equipment—Concrete pavement, separator support, pumps, conveyors, sumps, electric power, and building costs.
- Solids/liquid separator—Requires both solid and liquid waste handling equipment.

Figure 12–58 Vane axial and centrifugal aeration blowers

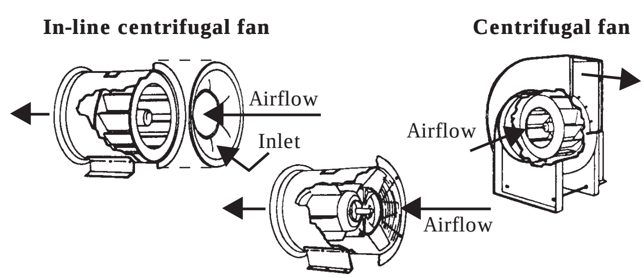
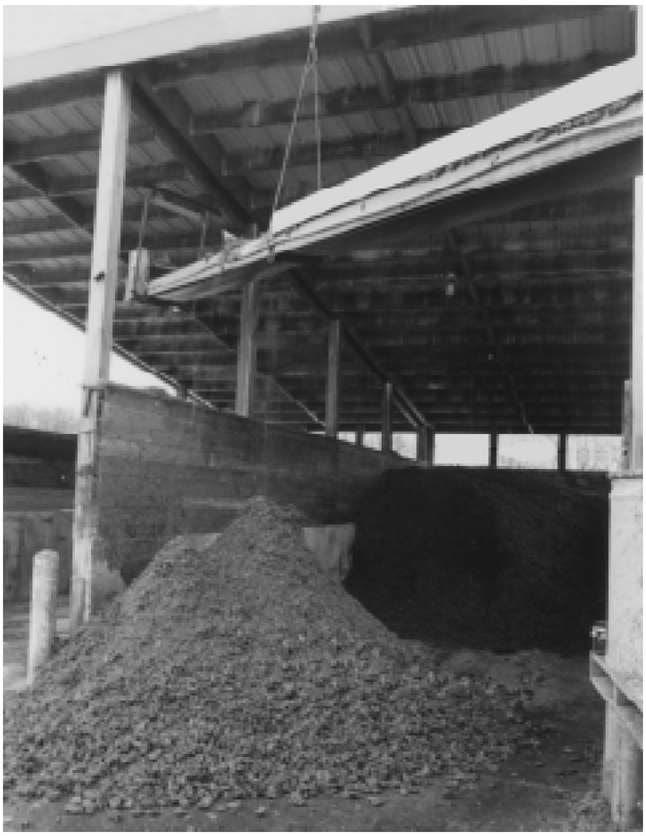
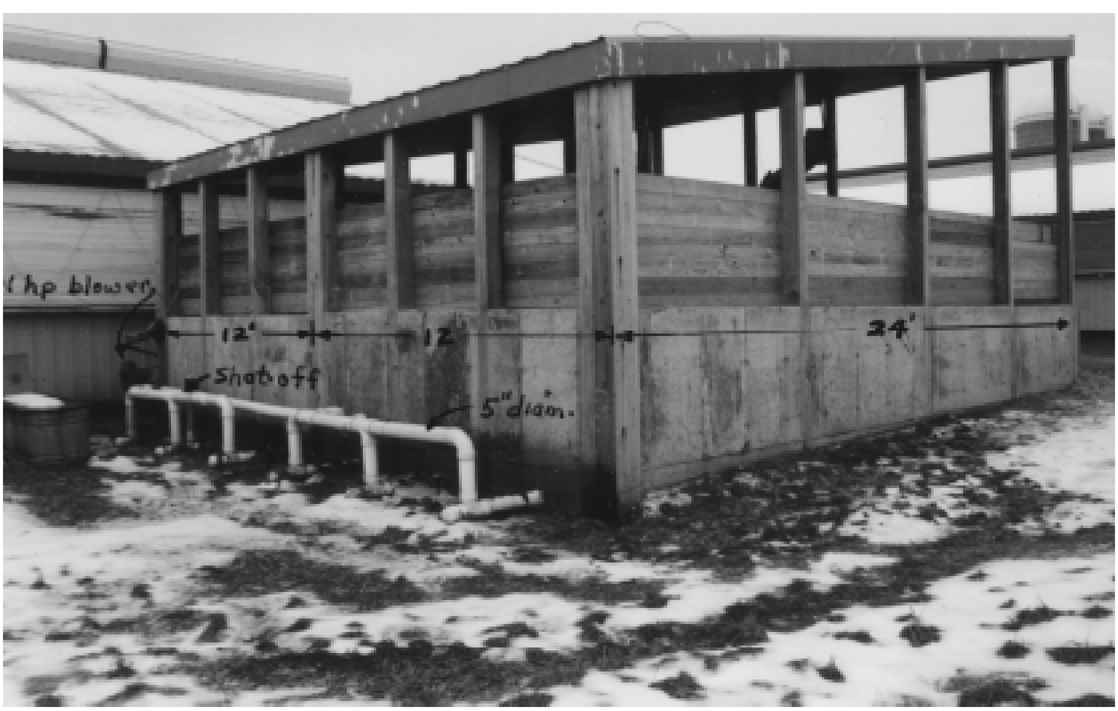


Figure 12–59 Aeration for separated dairy waste solids



Front view



Rear view

(1) Mechanical liquid, slurry, or semi-solid waste separators

The separation of liquid from solid waste requires some outside action or force to break down liquid tension. The force is generally gravity (settling) (fig. 12–60), but sometimes mechanical means, such as pressure, are used. Mechanical separators are described in chapter 10, section 651.1004(g). Tables 10–9 and 10–10 explain performance data for three different separators; however, such performance varies depending on waste quality and equipment management. Cattle slurry waste generally contains more large, readily-separated roughage pieces than does swine waste.

The capacity or throughput and the efficiency of separators are closely related. If a low efficiency (less separation) can be tolerated, the throughput capacity will be larger. In most cases high quality separation is desired. Separator equipment, however, is rated on how fast it operates (gpm).

If the waste is not already about 2 percent solids, it is generally diluted to about 2 percent solids for pumping to the separator. Mechanical separators, such as direct pressing, leave considerable volatile solids in the removed liquid. About a 60 percent efficiency is considered good (Moore et al. 1989; HHS 1990; Verdoes et al. 1992). In other words, about 40 percent of the solids remain with the liquid.

(i) Sedimentation basin—Sedimentation basins (ASAE [t] 1994) are a group of structures alternately known as sedimentation tanks, settling basins, and settling tanks. Their purpose is to slow wastewater flow to allow solid material to settle by gravity. Sedimentation basins are formed from a variety of materials including earth, concrete, wood, and fiberglass.

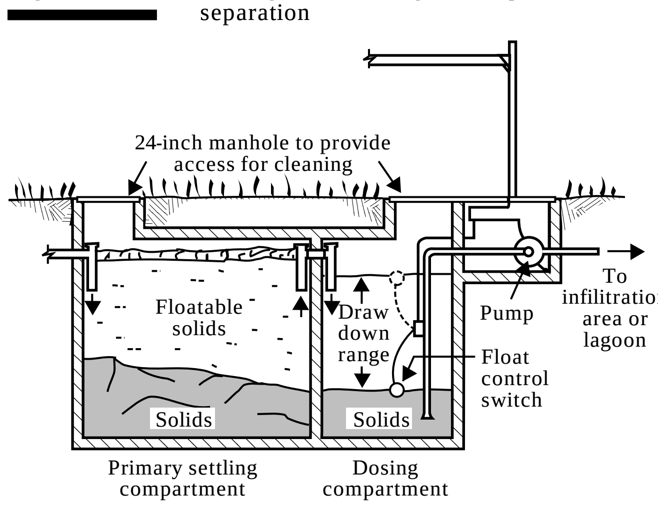
The Midwest Plan Service (MWPS 1985) distinguishes between settling basins and settling tanks. A settling basin is a structure designed to settle solids and drain the liquids, with the solids being periodically scraped and removed from the structure. A settling tank has a constant depth, and the contents of the tank are normally pumped on a regular basis. The MWPS terminology will be used here for descriptive purposes.

Figures 9–11, 9–12, and 9–15 in chapter 9 of this handbook show typical open gravity settling basin use. Their design is explained in chapter 10, section 651.1004(h). A diversion gate or valve in the flowstream can be used with two or more settling basins to permit one to dry and be cleaned while another is in use. Settling basins have particular application for intermittent large volume flows of wastewater.

In one study the settling efficiency was measured with time for different livestock specie waste slurries (Moore et al. 1989). This study reported that more than 60 percent of total solids from most dairy slurries can be removed in about 15 minutes of settling. The longer the slurry is held, the more solids that will settle or float. However, the increased settling time requires more volume.

A settling tank is used with a low-volume, relatively continuous flow of wastewater, such as recirculated lagoon flushwater, milkhouse washwater, or produce washwater (MWPS 1985). The design volume is based on a half hour flow detention time plus space for settled solids. Although earthen basin, metal, and other types of tanks are used, settling tanks are generally constructed of reinforced concrete or fiber glass. Surface baffles or a submerged inlet/outlet is used to hold back floating solids. Settled semi-solids need to be periodically removed by an in-place scraper or conveyor or agitated and pumped out.

Figure 12–60 Belowground settling tank, liquid/solid separation



(ii) Screens—The stationary inclined screen separator (fig. 12–61, see fig. 10–39) can produce a solids fraction of 12 to 23 percent dry material. This separator operates with liquid or slurry waste passing down and over the screen, permitting liquid waste to pass through the screen and semi-solids to pass over the end. In addition to wire mesh, round hole and slot types of separator screens are also common. Often these will have a sharp-edged hole or slot (when new) exposed to the slurry material to be separated. The hole diameter or slot width then increases slightly to assist liquid passage through the screen and to minimize plugging. The wedgewire screen, for example, permits smaller solids to readily pass on through once they get through the slot opening.

To reduce screen plugging and blinding, various sizes of screen openings and shapes and flushed, brushed, or scraped screen cleaning equipment are used. The extent of use depends largely on the waste quality. Some operators have found it necessary to periodically wash their screen separator with dilute boric or similar acid to remove solid chemical precipitate buildup (Buchanan et al. 1993).

Table 12–6 and tables 10–9 and 10–10 provide information about opening size for rectangular screen openings. Mesh number refers to the number of openings per inch. The larger the mesh number, the smaller the opening. In other words, a 10-mesh screen has 10 openings per inch, a 20-mesh has 20, and so on. The opening size dimension is the actual open distance of one side of the opening and does not include the wire that separates adjacent openings. The screen thickness limits the opening size, spacing, and support framework. A large opening allows more solids to pass through with the liquid, a small opening retains more liquid with solids. The size opening that screens out a major amount of solids is prone to plugging or blinding and needs frequent cleaning. This can affect separation quality.

In addition to collection and agitation pumps, the stationary inclined screen separator (as do most slurry separators) needs a 0.5- to 5-horsepower pump to raise 200 to over 1,000 gallons per minute of slurry above the screen. To help remove more liquid yet try to maintain throughput, press rollers are incorporated on a stationary inclined screen separator. They help produce a solids fraction of 15 to 25 percent dry material. More solids can pass through with the liquids, however, as the roll pressure is increased.

Figure 12–61 Wedgewire screen with sloped screen separator (MWPS 1975)

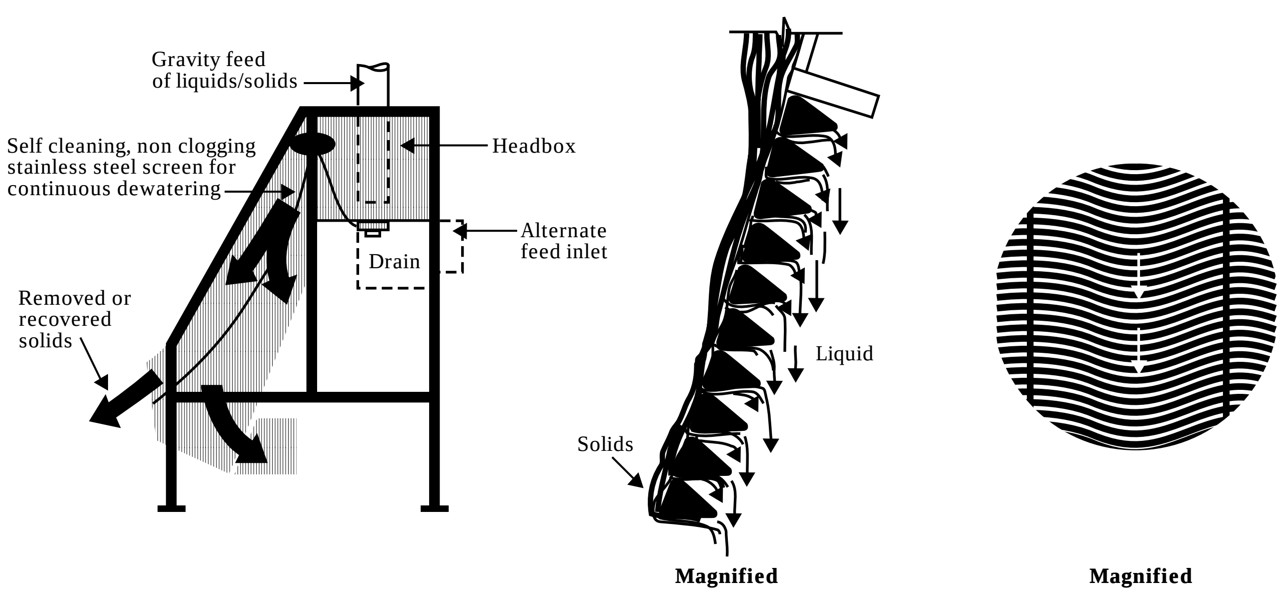
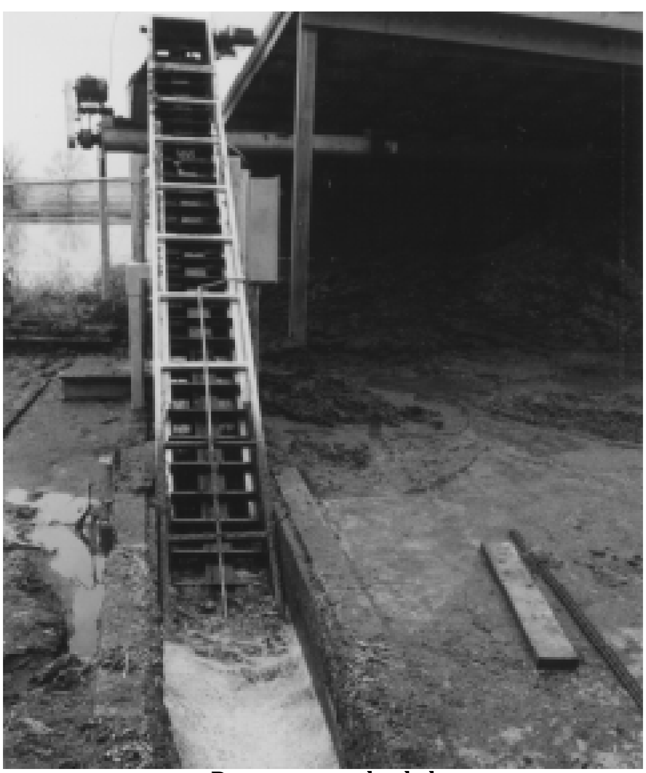


Table 12–6 Opening sizes for steel wire screens

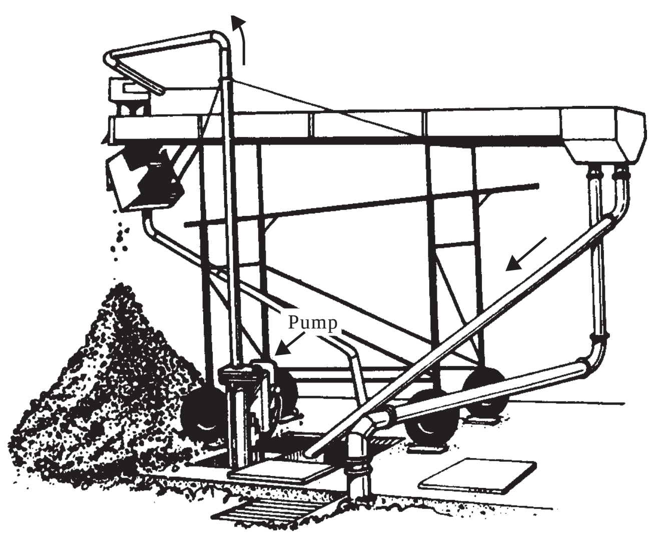
Mesh number (openings/inch)	Opening size (inches)
10	0.065
14	0.046
20	0.0328
28	0.0232
35	0.0164
48	0.0116
65	0.0082

***(iii) Conveyor scraped screen*—**The conveyor scraped drag screen mechanical separator (fig. 12–62) includes features of the static inclined screen and vibrating screen type separators. Agitated slurry or liquid waste is conveyed directly out from reception storage or pumped up onto platform made of closely spaced (slotted) steel rods or perforated screen with openings about 0.12 to 0.2 inches wide. The platform is generally 1 to 2 feet wide and 10 to 30 feet long. It may be horizontal or on a less than 30-degree incline. The waste is conveyed or dragged along over the openings by gutter cleaner or chain slat conveyor paddles. The liquid waste drains through the openings to storage, and semi-solids are conveyed or dragged along, dropping off at the end of the conveyor. A roll-press separator may be used to further separate out liquid as the semi-solids leave the end of the conveyor. A 2- to 10-horsepower electric motor is needed to drive the conveyor or drag chain at about 15 to 25 feet per minute. Throughput capacity varies from about 75 to 150 gallons per minute.

Figure 12–62 Conveyor scraped screen mechanical separator (courtesy Clay Equipment Corp.)



Drag conveyor loaded



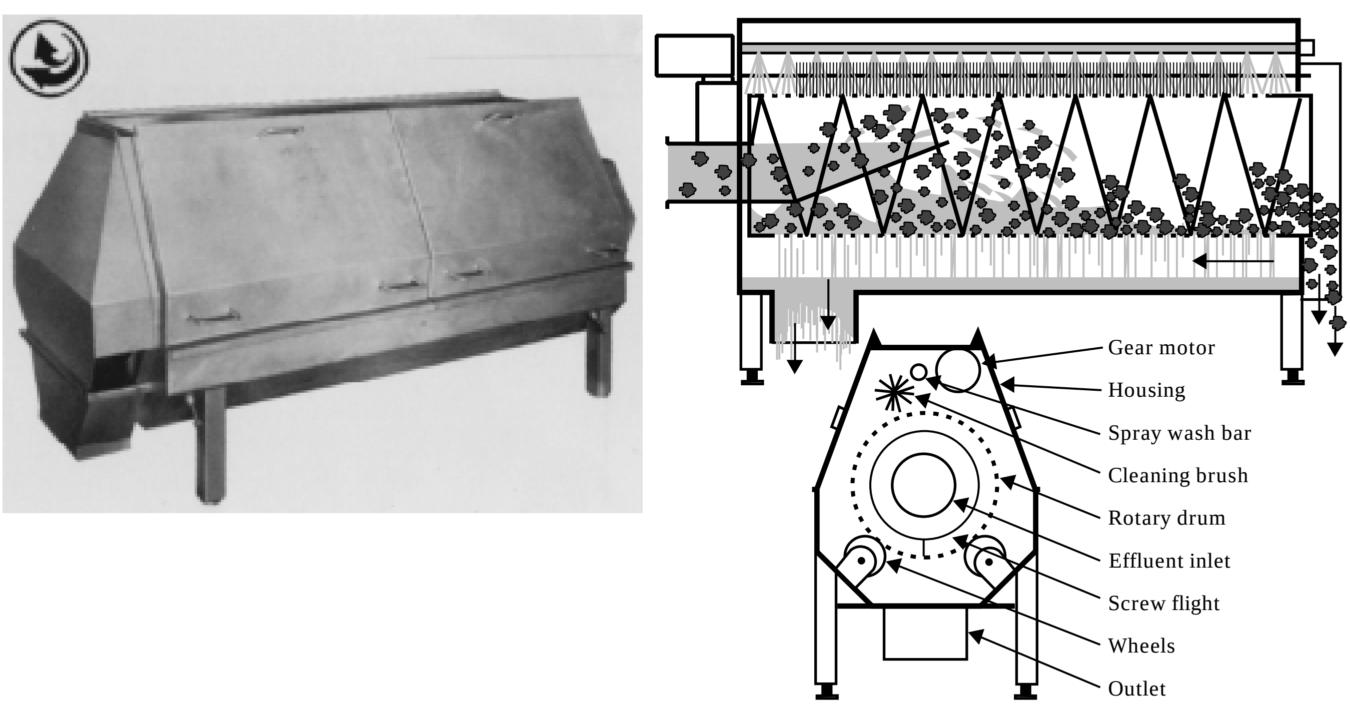
Pump and pipeline loaded

(iv) Rotating screen strainer—Perhaps more commonly used with vegetable processing, the rotating screen strainer (fig. 12–63) uses a perforated, horizontal cylinder that rotates at about 10 to 35 rotations per minute. The liquid waste to be separated gravity-flows into or onto (different models vary) the end of the rotating cylinder. Solids are pushed along by a rotating helix or scraped off the rotating screen and move out the opposite end. Liquid passes through the screen and drains to storage. Unless roller pressure is applied, the rotating strainer has relatively high volume and relatively low (15 to 25%) separating efficiency. Models are available with 500- to more than a 10,000 gallon per minute capacity, depending on screen size. The rotating screen strainer is comparable to the trommel screen separator (see fig. 12–69) that is used for solids sizing and separating operations.

(v) Vibrating screen—A vibrating screen separator (see fig. 10–39) is perhaps used more with continuous-flow, large capacity separation needs, such as aggregate, vegetable, or wood processing systems. This type separator has relatively high investment and durable construction. Material to be separated is conveyed into a wide, shallow container that has a replaceable bottom screen. The container vibrates both vertically and horizontally to move the material over the screen and minimize screen plugging. As the material flows into the vibrating container, the liquid or smaller materials pass through the screen and the large solids work toward the container's edge, fall off, and are removed. Some solids are broken up in vibration and pass through with liquids, lowering the separation efficiency with some materials.

(vi) Screw and piston press—A screw press separator (fig. 12–64) uses a straight or tapered screw (auger) of fixed or varying pitch contained in a perforated or slotted cylinder. Liquid or slurried waste gravity flows or is force-fed to enter at one end of the rotating screw. As it is forced along by the rotating screw, liquid waste drains through the cylinder enclosure and goes to storage. The semi-solids are pushed out the end. Adjusting the end retainer restricts throughput, which forces out more or less of the liquid through the cylinder enclosure. Power need is increased as the quality of separation is increased and the throughput is slowed. A 4- to 40-horsepower

Figure 12–63 Internal drum rotating solid and liquid strainer (courtesy of Schlueter Company)



electric motor is used for throughput of 10 to more than 5,000 gallons per minute, depending on the waste type. A separated solids portion to about 30 percent dry material is possible.

Agricultural engineers at the University of Wisconsin, Madison, developed a hydraulic powered piston press to separate solids out of slurry waste (fig. 12–65). Slurried waste is pumped up from a holding tank and drops into an internal-external slotted cylinder that surrounds a hydraulic-driven, donut-shaped piston. As the piston moves horizontally back and forth, liquid waste is squeezed out through the surrounding interior and exterior slotted cylinders that have 0.157-inch slot widths. The semi-solids are forced out the ends past an adjustable restrictor (Keener et al. 1993, Straub 1993).

A cylinder that has an 8-inch outside diameter processes about 60 to 80 gallons per minute of slurried dairy waste at 30 strokes per minute. The the dewatered fibrous material retained has about 25 percent of the total solids in the influent. A cylinder that has a 10-inch diameter processes about 100 to 120 gallons per minute. (This is being tested at the time this chapter was written.) Waste with long fibers, such as straw, is more easily processed than that with short fibers, such as ground newspaper. This separator has been in use at the 250-cow operation at the USDA Dairy Forage Research Farm, Prairie du Sac, Wisconsin, since 1990. Commercially available piston press separator equipment uses a horizontally operated solid piston arrangement used mostly for high solids filtering applications.

Figure 12–65 Piston type (double-acting) annular separator

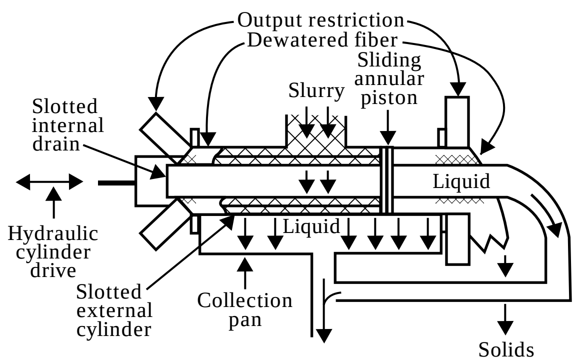
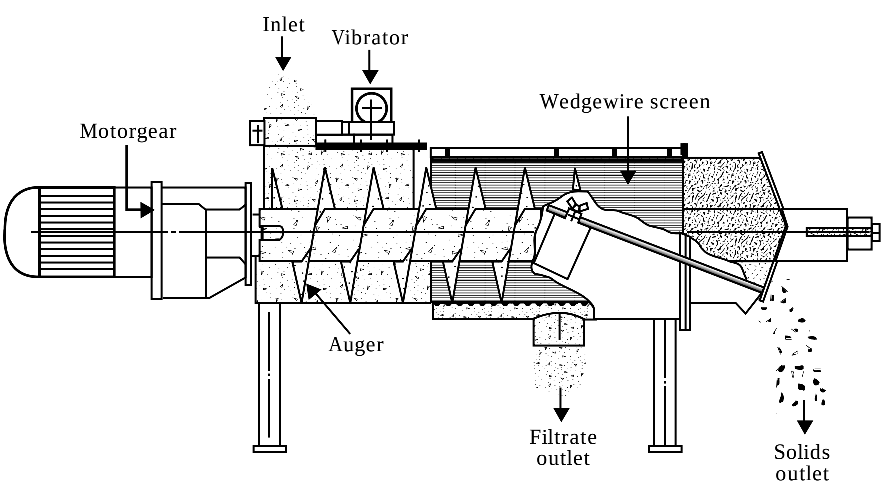


Figure 12–64 Screw-press type, cylinder separator (courtesy of Fan Engineering USA, Inc.)

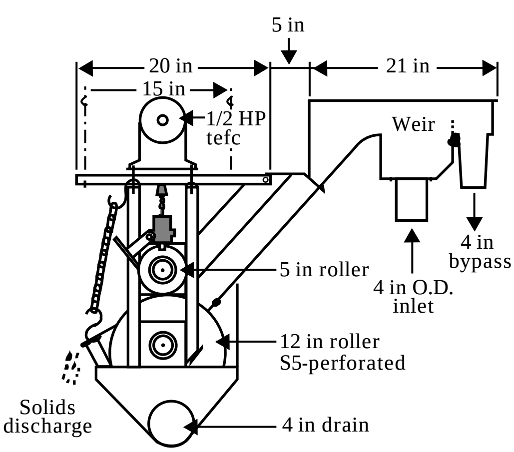


***(vii) Roll press*—**A perforated pressure roller or roll press separator (fig. 12–66) uses sets of rollers through which liquid waste passes. It is similar to a clothes wringer-washer. The upper, solid roller may be compressible while openings in the bottom roller permit liquid to drain through and away. The pressure-roller separator is often incorporated and used in combination with the stationary inclined screen and drag conveyor scraped screen separators to help improve their separation efficiency (see figs. 12–61, 12–62). In such applications about a 0.5- to 1-horsepower electric motor can power the rollers alone, while throughput depends on how tight the rollers are set together.

***(viii) Brushed screen*—**A brushed screen, roller press separator (see fig. 10–39) has screens lying side-by-side that provide two stages of separation. A multiple brush and roller assembly rotates over each screen, sweeping waste across the screen. Liquid waste is pumped into one side of the separator. The brush and roller movement forces liquid out through the screen. Larger solids on the screen get pushed off the separator at the opposite end. Small solids can be forced out with liquids depending on screen size and brush action.

***(ix) Belt pressure roller*—**The belt pressure-roller separator is similar to the roller press separator. The belt pressure roller separator (see fig. 10–39) uses two concentrically rotating belts to squeeze out liquid from liquid waste deposited between the moving belts. More adapted to filtering out fines from liquid waste, the liquid is squeezed through or out of the sides as the belts pass over adjustable spring-loaded rollers. The remaining solids are scraped off the belt to a conveyer.

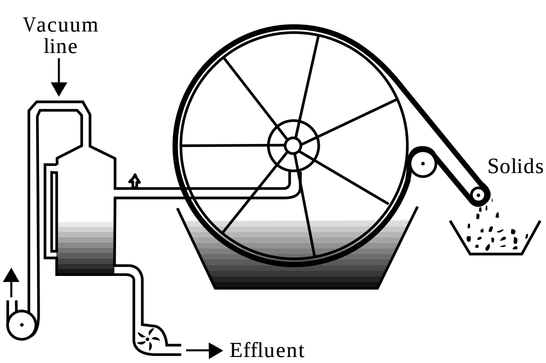
Figure 12–66 Perforated pressure-roller solid/liquid separator (courtesy Baler Equipment Co.)



Optional weir infeed

(x) Vacuum filter—A vacuum filter, horizontally mounted separator (fig. 12–67) has a cloth fiber cover over a belt or rotating perforated cylinder. An interior vacuum draws liquids out of waste that flows onto the cloth. The liquid passes through and drains away. The solids are scraped off the cloth cover at separation points and are conveyed to storage. Used with municipal and industrial processing, the vacuum filter is relatively efficient. However, throughput is low and filter plugging is a problem with certain solids sizes.

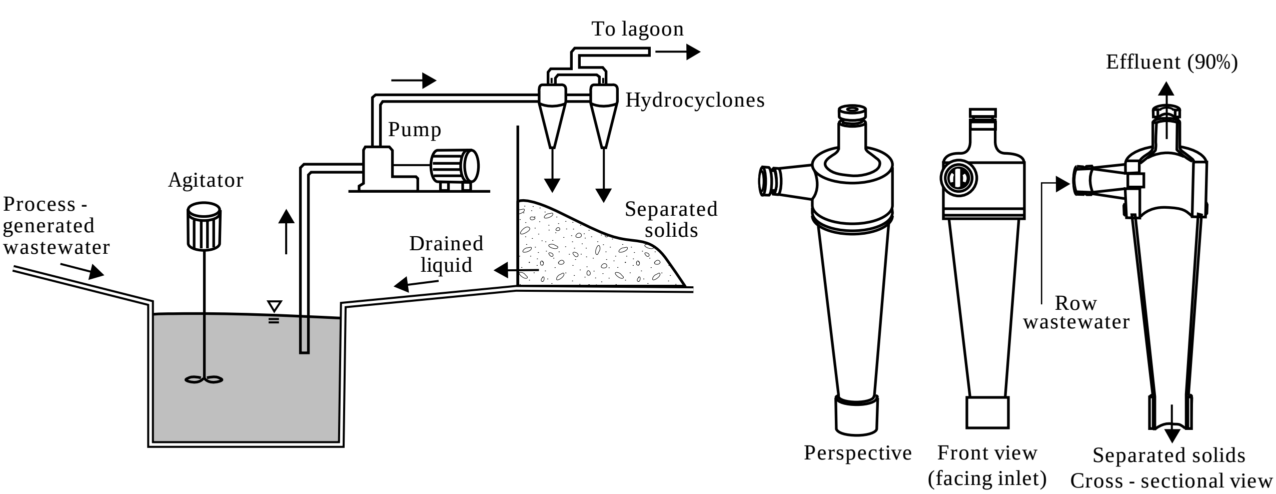
Figure 12–67 Vacuum filter separator



(xi) Centrifugal—A centrifugal separator uses centrifugal (outward velocity) force on liquid waste to separate denser solid material from the liquid. One type employs a relatively slow-speed, rotating cylindrical or conical screen. The waste is fed into one end where the solids are contained on the screen, scraped off, and discharged from the opposite end while the liquid passes through. This is comparable to the spin-dry cycle of an automatic clothes washer. Either a horizontal or vertical screen installation can be used.

A second type centrifugal separator uses centrifugal and centripetal (inward) forces on liquid waste forced horizontally into a conical-shaped bowl. Similar to the action of a feedmill dust collector, the liquid waste enters tangentially at the larger diameter of the cone at about 50 pounds per square inch (fig. 12–68). This causes a high velocity swirl or vortex. Semi-solid waste particles are propelled to the outside of the vortex and move downward toward the zero pressure outlet at the bottom. Liquid collects at the center and discharges out the top, along with the air. As forces on particles passing through the separator depend on the flow velocity, the operating pressure on the incoming waste affects separation efficiency. This dictates that the nozzle inlet and the cyclone be small to achieve minimum inlet pressure (Auvermann and Sweeten 1992).

Figure 12–68 Centrifugal-centripetal solids/liquid separator (courtesy AgKone, Inc.)



(2) Solid waste separators

A mechanical dryer may be needed to provide uniform moisture material for solids separation. A magnet under a conveyor or gravity flow chute can be used to sort out ferrous metal, generally from solid waste.

Although solids can also be separated by shape, density, and surface characteristics, one of several kinds of screening equipment is usually simplest. The screen opening size, shape, susceptibility to plugging (blinding), capacity, and cost should be considered in selecting screening equipment. Screening equipment can use brushes, vibration, forced air, or bouncing balls (below the screen) to reduce blinding. Screen openings of 0.25 to 0.5 inch are suggested for separating compost, depending on the material to be separated out. Small openings improve separation quality, but decrease capacity. Dryness of the material affects separator performance (e.g., more than 55 percent dry material compost is recommended).

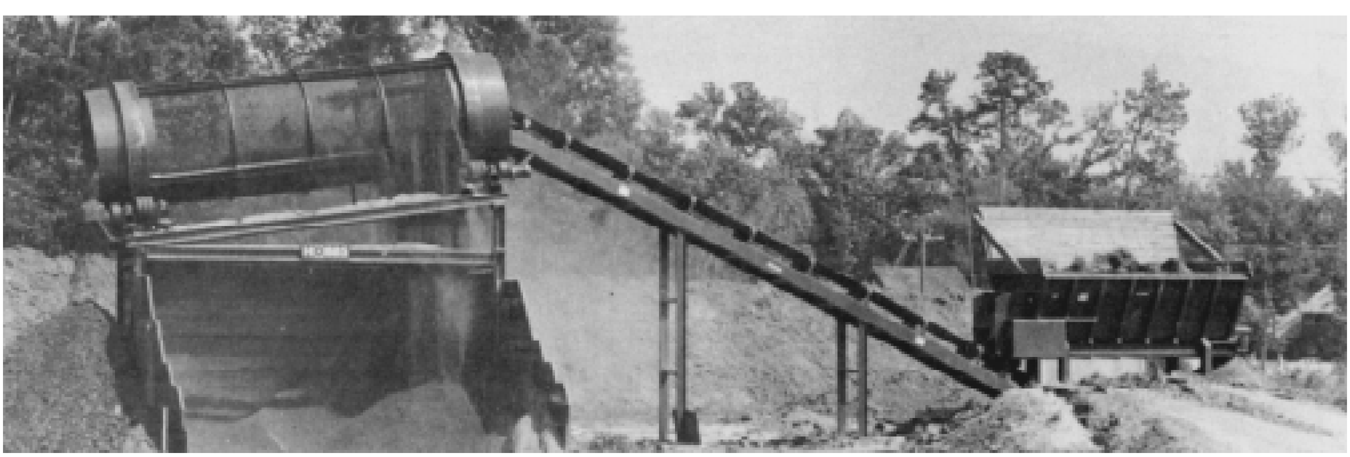
***(i) Trommel or rotating screen*—**The trommel screen separator is a long, rotating, inclined drum with openings (fig. 12–69). A gravity feed hopper, elevator auger, or chain-slat constant speed conveyor feeds a uniform material flow into the continually rotating drum. Screened material exits out the sides and is guided downward by a shield. Oversize material exits out the end.

Rotating drum equipment used with granular screening employs perforated metal, slotted metal, or wire mesh screen. Industrial trommel screens are available in different sizes, but generally are at least 3 feet in diameter and 10 feet long. They rotate at about 300 rotations per minute. Exterior rotating brushes can be used to clear screen openings. Depending on the capacity, power requirements vary from 5 to 50 horsepower. Screen sizes can be changed.

***(ii) Open screen conveyor*—**An auger rotating in an opentop, screened trough permits fine, dry, granular solids to drop through and separate from lighter, coarser solids while being conveyed. Coarse material is conveyed to the end. This separator can remove dry soil from wood chips, for example. Power need varies with speed, angle, and material conveyed, but would be about 2 to 4 horsepower per 10 feet of 0.5 to 1-foot diameter auger operated at a 25 degree angle at about 450 rotations per minute. The investment is relatively low as is the separation quality.

***(iii) Vibrating screen*—**A sloped shaker or vibrating screen separator uses a back-and-forth reciprocating motion to bounce material down along the length of a sloped screen (fig. 12–70). Material is fed onto the upper end of the screen and, depending on screen arrangement and hole size, either falls through the screen with the foreign material falling off the end, or

Figure 12–69 Trommel, rotating drum, solids separator (courtesy Amadas)



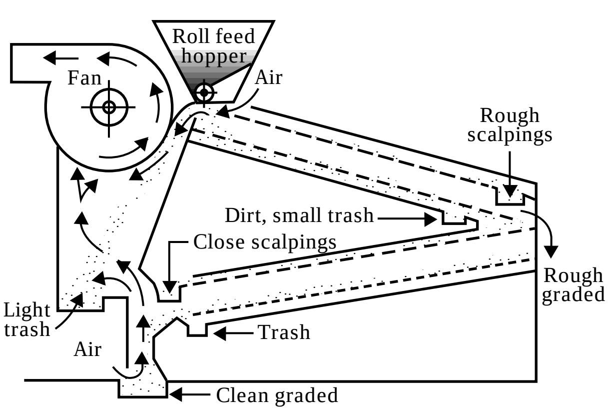
vice versa. Several screens can be used or changed, each with different sized and shaped openings, so most granular-shaped materials can be accurately sorted and sized. A controlled rate of forced air can be included with the shaker screen so lightweight material is blown out. Power need and throughput capacity are less than with comparable size trommel screen equipment, but the screened material quality is higher.

(iv) Slotted belt—A flexing belt screen separator uses a moving, wide slotted, flexible belt to carry along material that is metered onto it and is be separated. Sections of the belt are alternately flexed and snapped taut, throwing the material up and clearing the slots. The larger material is carried to the end, while the smaller material falls through the screen.

(v) Rotating screen or disc—A rotary screen or spinning disc separator has plates or discs with holes of selected sizes for material separation. Granular material metered onto the disc either falls through the disc openings or, if large, is spun off to the outside. The rotating screen solid separator is used in sawmills to separate sawdust from larger materials.

(vi) Fluidized bed—The fluidized bed separator was developed for more gentle separation of unwanted heavy solids from vegetables or other easily bruised solids. Fine sand moving over an adjustable air flow is blown upward to support the constant input of solids to be separated as they move through the separator. The selected solid is conveyed away while heavier solids fall and are separated from the recirculated sand. The fluidized bed separator has a high investment cost, relatively low power need, and high capacity, and is adaptable to special processing.

Figure 12–70 Sloped shaker screen solids separator



(e) Dehydrator, incinerator, renderors

Dehydrating, dewatering, or drying waste is explained in chapter 10, section 651.1004(e). Dried waste at about 85 to 90 percent dry material can be stored at normal conditions or packaged and distributed, depending on state laws about fertilizer quality, weed seeds, and disease. Dry, loose material is relatively easy to mix with other products for livestock feed, soil mulch, or fertilizer.

Shallow tray, batch or bin, continuous conveyor belt, rotary drum, and flash dryer equipment employ heated air blown over or through the waste.

The shallow tray dryer involves placing a 3- to 12-inch layer of material to be dried on a mesh screen or perforated metal floor. Hot air is blown through the material until it is dried to the desired level. It is then removed and another tray put on to dry. The continuous shallow bed dryer is similar except the material to be dried is conveyed through the heated airstream. The conveyor movement rate varies according to required drying time and operating temperature. One dryer arrangement is shown in figure 12–71. Available models are rated from 1 to 20 tons per hour capacity with a 3- to 25-horsepower blower motor and heater sizes to a million BTUs.

The rotating drum or inclined cylinder dryer is designed for use with high-capacity agricultural processing and waste drying (fig. 12–72). Wet incoming waste may need to be dewatered via short-term stacking, solid/liquid separator, or remixing with dried waste before entering the rotating drum dryer. This minimizes the formation of rolls or compacted balls as waste tumbles through the dryer. As wet waste moves through the drum, heat from a direct-flame burner is blown through the dryer in the opposite direction. This permits the hottest air to first evaporate water from the exiting drier material.

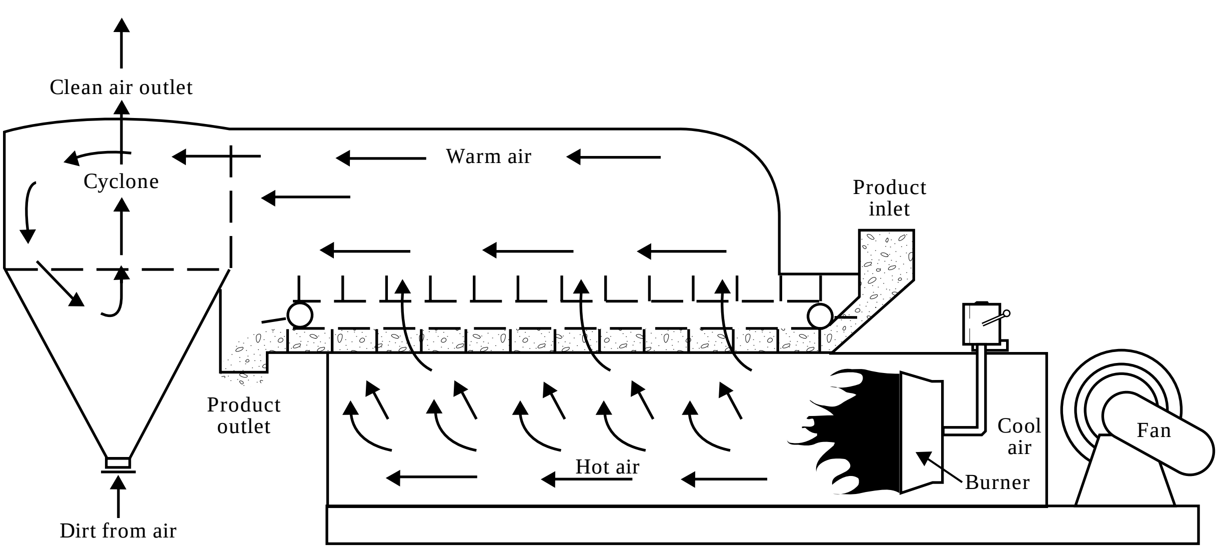
Dryer/dehydration equipment that has a relatively high capacity of 10 to 40 tons per hour of 50 percent dry material requires a high investment and has high operating cost. Odors from drying wastes can be a community problem. Operating power need from 10 to 125 horsepower and heat requirements to 30 million BTUs per hour may be required.

Mechanical drying of undiluted poultry waste has been extensively studied because of its high nutrients and total solids. The high investment and labor costs cause producers to not use mechanical drying of undiluted poultry waste inspite of the value of the final product. Heating air and forcing it through wastes to dry out moisture requires blower power and nearly 1,200 BTU of heat for each pound of water removed—if done at 100 percent efficiency. A ton of 40 percent dry material hay, for example (representative of some agricultural wastes), needs over 1,100 pounds, or 133 gallons, of water removed to make 90 percent dry material hay that is safe to store. Depending on weather conditions and efficiency, some 2- to 3-million BTU or 15 to 20 gallons of fuel oil equivalent would be needed. Research at Michigan State University indicated that 9.45 gallons of fuel oil were required to remove 1,000 pounds of water from poultry waste. Table 12–7 shows results from mechanically drying different kinds of animal excreta.

A pilot scale, odor-free waste drying system consisting of a continuous-flow crop dryer with an afterburner and heat exchanger was developed and its performance analyzed at the University of Guelph (Meiering et al. 1975). The exhaust air from the dryer entered the afterburner where odorous components and dust were oxidized by open-flame combustion at 1,200 degrees Fahrenheit. The burned air then flowed through the heat exchanger and heated the incoming air to the dryer. Complete odor elimination, except for traces of ammonia, was achieved in the drying of poultry and sheep wastes. Also safely dried was potato processing wastes that were generated in caustic soda and mechanical peeling processes. Nearly 60 percent of the heat generated in this process was recovered by the heat exchanger for the drying, which required about 2,165 BTU per pound of water removed. This is about 50 percent efficiency and would have been lower had the heat exchanger been excluded or poorly maintained.

Drying feedlot waste from the Fort Worth, Texas, Stockyards in 1964 involved wastes stockpiled outdoors in long rows and frequently turned to speed outdoor drying and decomposition, reduce odors, and kill vegetative growth. After several weeks the product was ground, shredded, moved through a gas heated dehydrator drum, screened, weighed, sacked, and conveyed to a truck for distribution (Compost Science 1964).

Figure 12–71 Continuous flow shallow tray dryer (courtesy Jet Pro, Inc.)



Incineration equipment is used for destroying dead animals and poultry. This equipment is useful for animal disposal and disease control with confined livestock production and animal health care operations. Oil-fired incinerators are available for a 100- to more than 500-pound animal load capacity (fig. 12–73). Suggested incinerator size is that needed to handle one day of animal loss. Burner capacity and door size affect actual use. An air-pollution approved incinerator has high investment and operation costs. These incinerators use 1.5 to 2.5 gallons of fuel per hour for about 2 hours per load. Regular maintenance, cleaning, and ash disposal are required.

Large scale incineration of waste has generally been limited to commercial situations that require specific planning and design. The kind of waste, its supply, hauling, odor from and appearance of stored unprocessed waste, and particulate emission must be considered. Equipment investment is high, and operation costly. Some 10 to 30 percent of the initial dry matter remains as ash that requires disposal (Agriculture Canada 1980). Fluidized-bed furnaces and incinerators use agricultural wastes as fuel (Annamali et al. 1985, Clanton 1993, Zygmunt 1992). Agricultural processing plants (e.g., seed processing) adapt this equipment for their in-plant energy supply and use their own dry processed waste. Some energy conservation grant support or other incentive can assist with costs. This nearly continuous-operating equipment can be effectively designed and used by regular skilled employees.

Rendering plants use dead animals for manufacturing useful products. Because it is a large capacity operation, a rendering plant requires installation approval and careful operation. An adequate supply of dead animals and a market for the products are essential. A regular pick-up service with enclosed trucks is needed. Because of the high investment and monitoring needs, the few installations that are currently in business are sparsely located to accommodate livestock production and supply.

Figure 12–72 Rotating drum type dryer/dehydrator (courtesy Vincent Corp.)

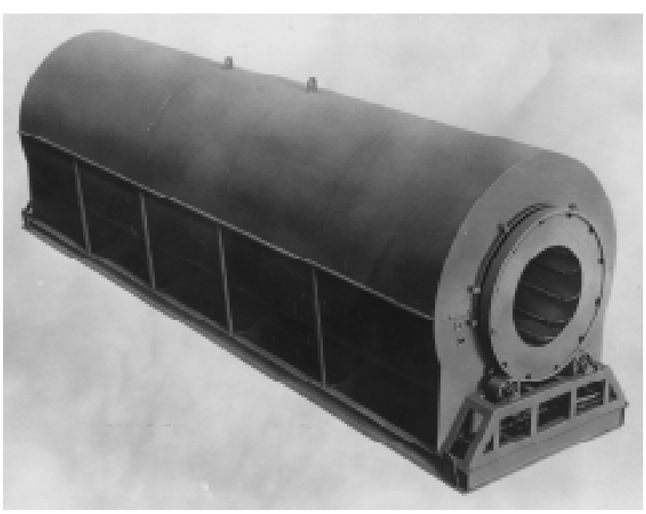
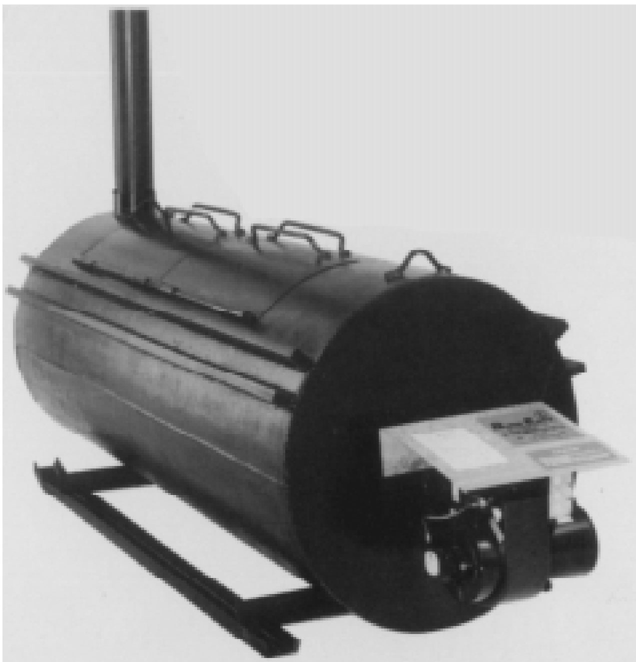


Table 12–7 Dryer performance with animal excreta (MWPS 1975)

Excreta source	Fresh excreta (lb/hr)	- - - Moisture - - - initial (%)	final (%)	Fuel use (gph)	Elec. use (kW)	Efficiency (%)
Poultry	340	76.3	11.1	2.4	4.2	72
Bovine + 2% straw	243	82.4	12.0	2.6	4.2	52
Swine	225	72.2	12.5	2.4	4.2	44

Figure 12–73 Incinerators for dead small animal disposal (courtesy R & K Incinerator Co. and Shenandoah Mfg.)



651.1206 Waste transfer equipment

The movement or transfer of agricultural wastes is described in chapter 9, sections 651.0904(e) and 651.0906. As further explained in chapter 10, section 651.1005, transfer equipment can be an extension of the waste collection equipment. The equipment that has common use either for collection or for transfer of waste is explained in section 651.1203. It includes:

- Tractor front-end loader
- Skidsteer and articulated-steer loaders
- All-wheel drive front-end loader
- Ramps and bumper walls
- Air-pressure/vacuum pumps
- Large piston pumps
- Earthmover scrapers

Solid waste is commonly transferred a batch or more at a time (i.e., scoopful, wagon load) and at a relatively low rate. It is relatively dense and not easily moved. While batch movement is intermittent, a relatively larger quantity of semi-solid, slurry, and liquid waste generally is transferred at one setting with continuous flow type equipment than with other equipment. Depending on what is calculated and how (e.g., labor, investment, odor, appearance, nutrient), the cost of actual dry matter transferred is probably similar. The liquid portion facilitates waste transfer, but, unless needed for irrigation itself, has little value and adds to transfer quantity.

(a) Augers and conveyors

A standard pitch auger that is 0.3- to 1.5-foot in diameter can be used to transfer solid, semi-solid, and liquid wastes. A clean auger intake and relatively tight auger fit within its housing assist throughput. A short pitch, sometimes called *double flight* auger (twice the flighting per foot) aids slurry or liquid waste transfer if operating at relatively steep inclines. Table 12–8 shows how water throughput changes with auger size, speed, power, and elevating angle. With slurry and semi-solid wastes, less throughput can be expected than that for liquid waste (MWPS 1975).

Although designed to transfer semi-solid waste, power requirements are relatively high for larger augers—about 1 horsepower per 2 feet for an auger that is 13 to 16 inches in diameter and operates at 200 rotations per minute. If stopped when full, auger startup is difficult. A 16-foot-long auger, that is 16 inches in diameter, operating at about a 30-degree incline should have about a 750 gallon per minute throughput when powered with a 7.5-horsepower motor at 200 rotations per minute. Most manufacturers use a plastic liner or pipe housing because it operates smoother and quieter and is resistant to wear and corrosion. Augers up to 40 feet long are available that are designed for slurry and semi-solid wastes (fig. 12–74). Some models that are more than 100 feet long and 0.33 to 1 foot in diameter are available for granular solids transfer.

(b) Pumps

Piston plunger and air pressure or vacuum pumps are explained in section 651.1203.

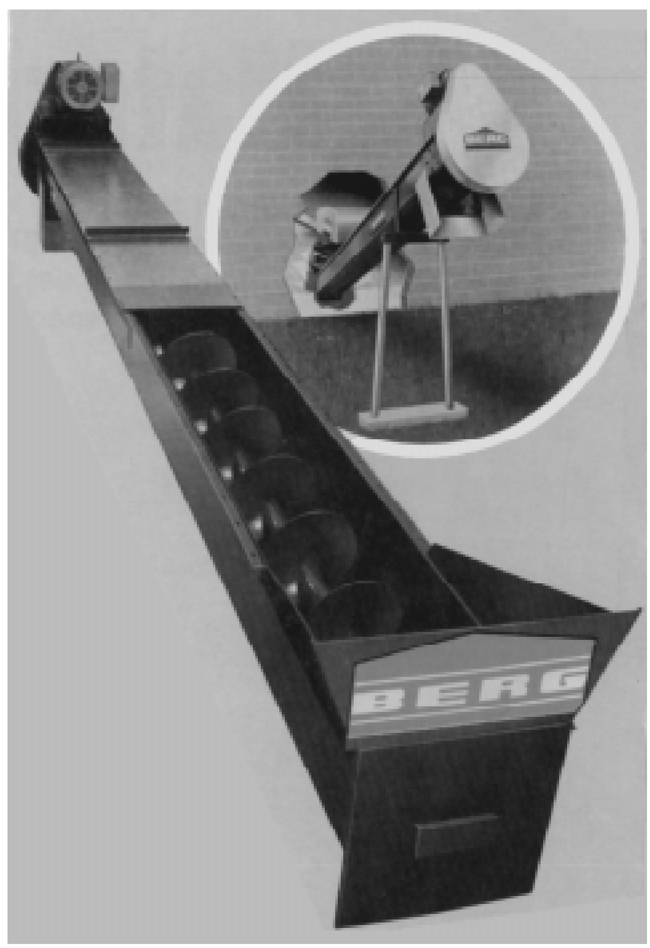
A variety of either variable or positive displacement pumps move liquid, slurry, and semi-solid waste to storage, tankers, or irrigators. Pump selection and rating depend on the amount and type of solids in the waste (see chapter 4 and sections 651.0905 and 651.1101), capacity desired, head or operating pressure needs, and available power. Table 12–9 compares the major characteristics of different pumps used for pumping waste. Because of the many model variations (inlet, outlet, impeller, speed, power), the manufacturers' literature on use and performance of a particular pump needs to be reviewed.

Measures are available to protect a pump and power supply against plugged pipes or nozzles, loss of prime, overheating, and lubricant loss. They include pressure and temperature gages, fuses, circuit breakers, and pressure switches. Lightning grounding is especially needed with exposed pipe irrigation pumping. Pressure surges in the discharge pipe (water hammer) are troublesome in starting high capacity pump systems. An open valve in the discharge pipeline can be slowly closed to reduce water hammer when pressurizing a system. A surge tank reduces water hammer as well.

Table 12–8 Auger (11 ft) speed, power, and capacity for water

4-inch diameter auger				6-inch diameter auger			
rpm	hp	angle (%)	gpm	rpm	hp	angle (%)	gpm
1,500	0.8	45	32	950	2.0	45	80
		60	17			60	40
		90	10			90	—
1,700	1.6	45	48	1,150	2.8	45	180
		60	33			60	130
		90	19			90	85
1,900	2.6	45	66	1,350	4.0	45	330
		60	51			60	255
		90	30			90	200

Figure 12–74 Auger elevator slurry waste conveyor (courtesy Berg Equipment Company)



The wear on most pump bearings and seals is rapid when pumping waste. The severe pumping conditions also damage controls and valves. Regular lubrication and cleanup extend pump life and performance. A spare pump should be readily available to replace essential pumps in a waste system when they break down.

Pump inlet and outlet pipe configurations affect performance. An inlet or outlet pipe that has a smooth, funnel shaped transition or a gradual corner without a sharp edge or turn, or both, aids flow (see fig. 12–91). This is especially helpful where the flow rate is high. The diameter of the inlet and outlet pipes should match that of the pump openings. A minimum of bends, elbows, and other flow restrictions in the pipeline improves flow and reduces power and plugging.

Exclude foreign material, such as twine, hair, wood pieces, broken iron, afterbirth, stones, and plastic from waste to help prevent plugging and breakage. A screened pump inlet, if used, needs a large screen area with relatively large openings to reduce plugging. A screen is most efficient with liquid waste that has few large solids and at low pumping rates. Locating the pump inlet above the bottom of the waste impoundment and below the surface minimizes inlet plugging (see fig. 12–28). Adding dilution liquid to waste aids pumping, but adds to waste quantity, storage space, hauling, spreading, and possible water supply problems.

Table 12–9 Waste pump characteristics summary (MWPS 1985, Patronsky 1978)

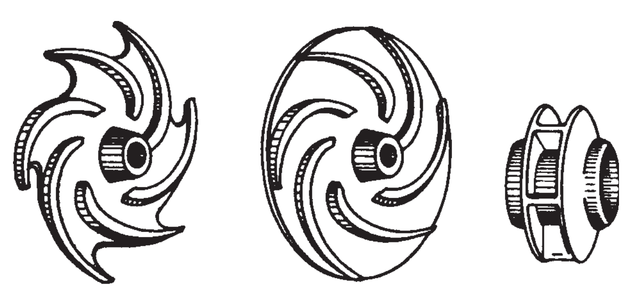
Pump type	Max. solids (%)	Agitate dis. (ft)	Pump rate (gpm)	Pump head (ft)	Power (hp)
Hi-pressure centrifugal	<10	40-60	1,000	200-300	80+
Chopper-agitator	10-12	50-75	<4,000	25-75	65+
Impeller agitator	10-12	75-100	<5,000	30-35	60+
Submersible	10-12	25-50	<1,000	10-30	<15
Helical screw	4-6	30-40	<300	200+	40+
Hollow piston	18-20	—	<150	30-40	<15
Solid piston	18-20	—	<150	30-50	<10
Pneumatic	12-15	—	<150	30-40	<10
Vacuum	8-10	20-25	<300	—	50+
Diaphragm	10-12	—	<300	100+	25+

Pump use and waste handling system performance are assisted by waste storage construction design features. Access space, pumping sump, agitation mixing, proper pump location, and intake protection are needed in addition to the correct pump selection (see section 651.1204). The solids and liquids in liquid, slurry, and semi-solid wastes need to be thoroughly mixed so the solids are not left behind when these wastes enter the pump.

(1) Variable displacement centrifugal pumps

Centrifugal pumps are variable displacement. They are widely used for waste pumping because of their simplicity and range of capacities. These pumps have a power shaft with an attached impeller that rotates inside an enclosed housing. Gravity-flow liquid enters the housing near the center of the impeller and is forced outward by the rotation of the curved impeller blades (fig. 12–75). The higher velocity at the outer end of the blades and low pressure at the impeller center cause the liquid to flow.

Figure 12–75 Centrifugal pump impeller types (MWPS 1985)



Intake restrictions or plugging cause air-pockets (cavitation) by the impeller. This reduces flow and can hasten the impeller wear, especially where high-pressure pumps are used at a high speed. Because the pumped liquid can slip past the rotating impeller, the liquid displaced varies—hence the name *variable displacement.* As slippage increases and further lowers efficiency, the pump operating pressure is increased. Pumping capacity, pressure, and power needs depend on design and construction of the impeller, the impeller enclosure, and its inlet and outlet.

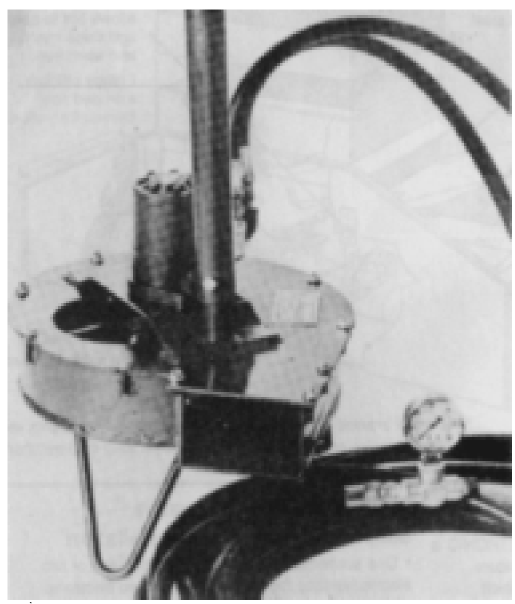
Established pump manufacturers design, develop, test, and manufacture a variety of centrifugal pumps for most uses. Models vary by size, impeller type and clearance, pump inlet and outlet, bearing seals, and drive arrangement. Selected models are often recommended by agricultural waste pumping equipment manufacturers that assemble pumping equipment for transfer, agitation, pumpout, and irrigating waste.

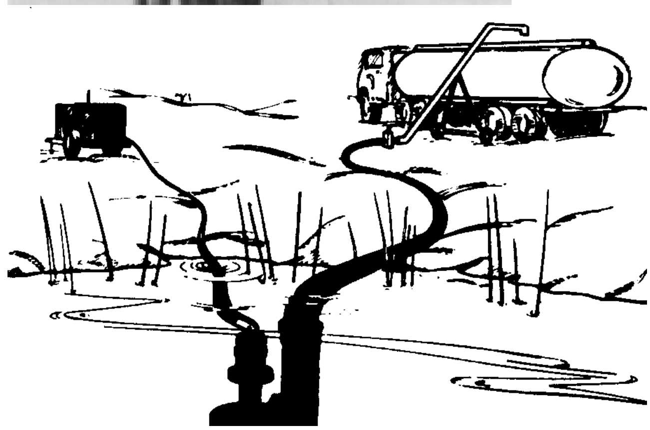
A closed impeller is efficient with liquid waste, but plugging with tough, stringy solids and chunks can be troublesome. A closed impeller pump is useful for high pressure irrigation or recirculating liquid for flushing. A semi-open or open impeller is less efficient, but is also less prone to plugging and is able to handle semi-solids. Although generally inefficient, a sloped and curved, semi-open impeller design minimizes flow cavitation and solids plugging. A sharp, hardened, chopper-blade attachment at the pump inlet (see fig. 12–42) can break up tough materials ahead of the impeller. The blade must be kept clean and sharp because a dull blade winds-up stringy materials, which restricts the flow.

Changes in the pressure at which a centrifugal pump operates efficiently can be made by changing the operating speed. However, when this is done the discharge and power required also change. Pump discharge generally increases directly as the speed increases; the pumping head increases as the square of the speed; and the power required increases as the cube of the speed. For example, a pump operating at 500 rpm could be expected to pump twice as much when operated at 1000 rpm. However, it would operate at half the operating pressure and use 8 times the power.

Liquid priming is necessary to start a centrifugal pump. Priming consists of filling the suction pipe and impeller enclosure housing with liquid to expel the air and cause suction as the impeller begins turning. A gate valve on the discharge side and a small hand pump attached to the volute are a usual priming pump arrangement. Holding liquid in the pump when stopped using one-way flow valves also is used, but plugging and leakage are problems. Priming becomes more difficult as a pump wears and air leaks develop around bearings. Some large capacity pumps have a separate small, powered priming pump. Locating (submerging) the pump in the liquid to be pumped eliminates hand priming (fig. 12–76).

Figure 12–76 Hydraulic motor powered centrifugal chopper pump (courtesy Liquid Waste Technology)





The practical limit of liquid suction for most centrifugal pumps is 22 feet at sea level, 17 feet at 5,000-foot elevation, and 14 feet at 10,000-foot elevation. Pumps will operate beyond these limits, but their performance is seriously reduced by cavitation or non-uniform liquid flow through the pump. Elevation can also affect vacuum pump suction and pumping performance (see fig. 12–88).

(i) Transfer—Generally, two types of pumps, submersible and vertical shaft centrifugal, pump liquid and slurry waste from reception storage to long–term storage or separation. The relatively small, submersible, 0.5- to 15-horsepower centrifugal type (sump) pump (fig. 12–77) is designed to simply sit on the pump chamber floor. It has a flexible power cord and pump outlet pipe. This type pump is messy to use and difficult to service. Industrial and larger models use a raise and lower attachment and hose disconnect.

The submersible pump is designed and constructed, usually with an electric motor, as a complete waterproof unit to be immersed in the liquid to be pumped. This design makes it self-priming. An automatic on-off float-control switch can be an integral part of the pump unit.

Typically, a submersible centrifugal pump is used to transfer 50 to about 200 gallons per minute of liquid or slurry waste from a sump to a reception tank, solids separator, or lagoon, or to recirculate lagoon water (see fig. 9–9). Larger models are available. Those that are powered by a hydraulic motor can pump up to 3,000 gallons per minute (fig. 12–76) at high pressures if they are designed and constructed with an enclosed impeller. This equipment is higher cost than the smaller models, but is simpler to use, is portable, and the speed can be readily varied.

A second type transfer pump, used with reception storage, has a 4- to 8-foot-long vertical shaft to the impeller. The motor is above the waste level, and the centrifugal pump is immersed and self priming (see figs. 12–77, 10–41). Although this pump cost more than the submersible type, the power supply and service are simpler and less messy. Models are available that use 0.5 to 25 horsepower motors and have a capacity of up to 2,500 gallons per minute at zero discharge pressure.

(ii) Chopper-agitator—The vertical shaft and inclined shaft chopper-agitator pump (see figs. 12–45, 12–48, 9–8, 10–16) typically employs a 10- to 20-inch diameter semi-enclosed impeller. This impeller has a relatively wide clearance, which helps to avoid plugging. See section 651.1205 (b) for more details.

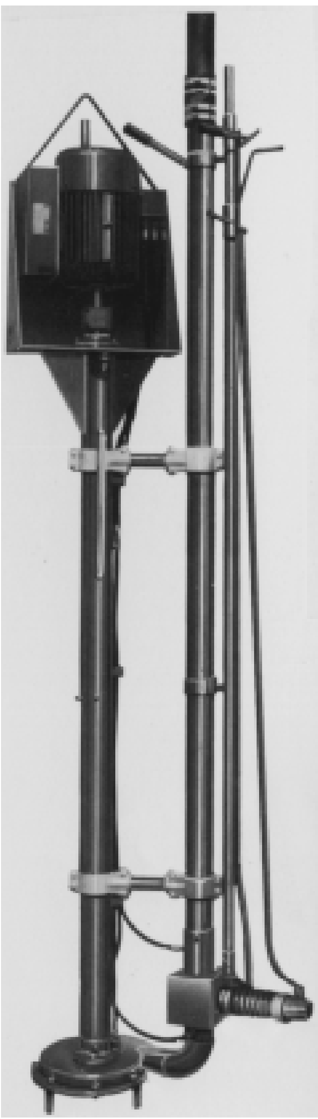
Generally a chopper-agitator pump impeller is individually welded and steel plated. Its bearings and seals are relatively rugged and simple in their design. The impeller runs at relatively low speeds at high volumes and low head.

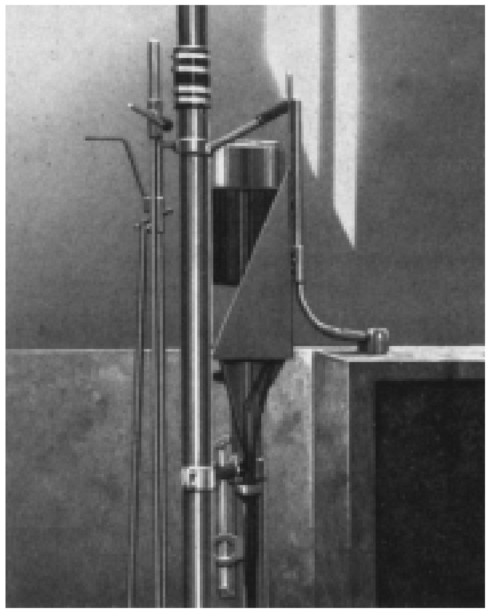
Although a hot-dipped galvanized coating is more durable, most chopper-agitator pumps are painted. Pumps in various sizes and capacities can pump up to 4,000 gallons per minute of waste when new. The pumps require 15- to 140-horsepower motors. Some models work to a depth of 12 feet. Most pumps are tractor PTO powered; some use electric or hydraulic motors. PTO power is less investment, but straight shaft alignment is important for smooth operation and minimum power train wear. Trailer tow models are simpler to hitch, move, and park in place. The 3-point hitch models use less space and cost less.

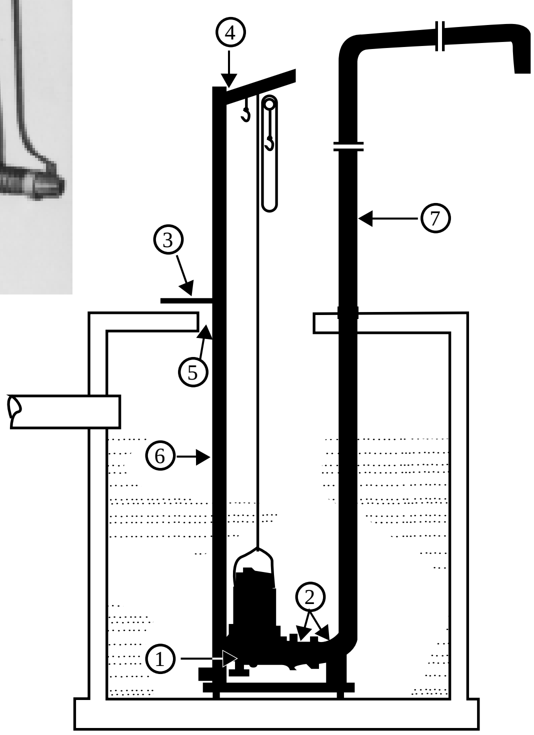
(iii) High pressure and capacity—Centrifugal pumps with a horizontal power shaft and closed impeller are available. These pumps are engineered with close tolerances, securely sealed bearings, balanced power shafts, and other features for sustained operation at high rpm's, pressure, and throughput.

Impeller end thrust is high with all the severe operating conditions experienced by operations pumping several million gallons per year. The end thrust forces waste past the seals and into bearings. High capacity pumps are used for liquid and slurry waste agitation and pumped waste spreading (see figs. 9–18, 10–18). The 80 to 150 horsepower needed for more than 100 pounds per square inch pressure and 500 to 1,000 gallons per minute throughput is provided by a stationary engine, electric motor, or tractor PTO (see fig 12–92). A separate primer pump is needed on these models to execute pumping startup. Two such pumps may be used in tandem to overcome pressures in pumping waste several miles via pipeline to a towed injector field spreader or irrigator (see fig. 12–103).

Figure 12–77 Submersible and vertical shaft transfer pumps (courtesy J. Houle & Fils Company)







1. Submersible electric pump with chopper blades to cut hair, bedding and other manure solids
2. Discharge nozzle and outflow pipe can be uncoupled by rotating control handle 3 at safety platform
3. Control handle
4. Lifting davit with portable chain hoist
5. Guide bracket bolted to safety platform or tank top
6. Guide bar controls pump position when coupling at 2 or hoisting pump 1
7. Discharge pipe

ways and Stairs, explains design and installation recommendations (ASAE [o] 1994). Briefly, the recommendations are:

- Space 16-inch wide rungs a maximum of 1 foot apart.
- Allow 7 inches of toe space in front of rungs.
- Use a 27- to 30-inch cage clearance about the ladder.
- Provide work landing platform access.

A waste storage ladder location in plain view by others is preferable. A portable ladder stored away from the waste storage can help deter unauthorized access (see figs. 9–6, 10–18). When in use, the portable ladder should be securely attached to the storage structure to prevent it from falling away and stranding the user. A ladder permanently attached to a storage structure needs to terminate beyond ordinary reach or an entry guard or gate must be used. The attached ladder should terminate at a height of more than 8 feet above the ground. A sunlit location for the ladder helps to quickly dry the ladder and is naturally well lighted.

A ladder permanently located inside a waste storage structure obstructs cleaning. It will also corrode and become unsafe as its deterioration is hidden by waste and poor light. A portable ladder, removed and stored when not in use, is a better alternative.

(b) Storage exterior accessing

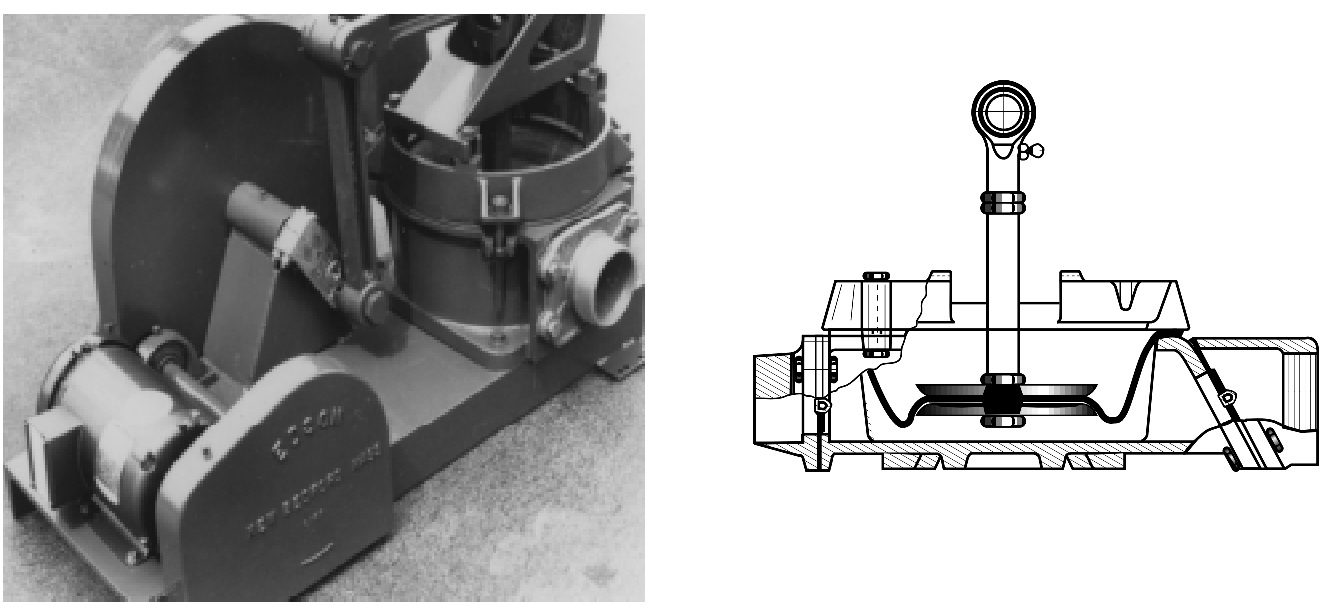
Waste storage agitation and emptying equipment needs overhead clearance and turning space access (see figs. 9–6, 9–8, 10–12, 10–16, 12–47 to 12–49). An example:

> A vertical wall, belowground, semi-solid/slurry storage structure that is up to about a 60-feet across and 12 feet deep can be agitated and pumped from one pump station using the same centrifugal-chopper pump used for filling the storage. A circular storage shape agitates in less time and encloses more storage capacity than does an equal perimeter length of a rectangle or other storage shape—everything else being equal.

Tables 12–3a and 12–3b can be used for estimating comparative sizes. For example, to store 21,600 cubic feet of waste would require a storage structure that is a 24- by 100- by 10-foot rectangle or a circular unit that is 55 feet across and 10 feet deep.

Additional access space or larger agitation equipment is needed for larger storages, especially for semi-solid waste. An impeller-type agitator (see figs. 10–16,

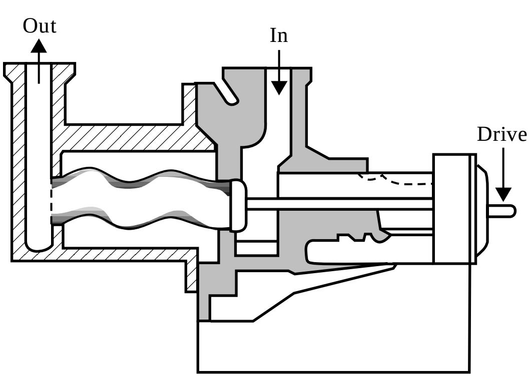
Figure 12–78 Diaphragm pump (courtesy Protek Specialty Company)



The diaphragm pump is commonly use by custom operators that pump or haul sewage sludge where performance is more important than high capacity. It is also used as a hand-operated primer pump with a high capacity centrifugal pump. Another common use for this type pump is for an automobile fuel pump. It can operate dry and be relatively trouble free with liquid and slurry wastes.

(iii) Helical rotor—A helical rotor, or rotary screw, pump (fig. 12–79) can pump liquid, slurry, and semi-solid wastes at pressures of up to 450 pounds per square inch. The pump is powered by a PTO or electric motor, so the operation is smooth and quiet. Sand, stones, and the metal hardware, however, prematurely wear out the composition material of the pump chamber. This chamber wear causes leakage that destroys the high positive displacement capability of the pump. Helical rotor pumps are used for slurry waste irrigation pumping. Some models can move up to 300 gallons of waste per minute at 150 pounds per square inch using a 50-horsepower motor.

Figure 12–79 Helical rotor pump (courtesy Continental Pump Company)



651.1207 Waste utilization equipment

The alternative end uses for agricultural wastes vary, and each use employs various equipment. Waste utilization is explained in sections 651.0605 and 651.0904(f). Land application is reviewed in sections 651.1006(a) and (b) and 651.1102(c), and biogas production in section 651.1006(d). Refeeding wastes to livestock, pyrolysis (a chemical change brought about by heat), and using waste as fuel are other alternatives, but they have limited applications to date (Annamali, et al. 1985, Landen 1992, MWPS 1985). Although a viable option, direct selling of raw waste is seldom done as timeliness, costs, weed seeds, and disease or organism spread are problems (Clanton 1993). NRCS considers solid/liquid separation, composting, and incineration of agricultural waste as treatment rather than utilization (section 651.1205).

Soil fertility levels and waste spreading use are monitored by soil sampling and land-grant university or commercial testing laboratory analysis. A direct reading nitrogen meter is available to directly measure waste nitrogen content (see fig. 12–122). The method for measuring the moisture content of waste is described in table 4–1.

(a) Hauled waste spreading equipment

The major use of agricultural waste is for crop fertilizer via field spreading. Equipment used to haul and field spread includes:

- Box spreader with floor conveyor/rear beater unload
- V-bottom box spreader with side or rear unload
- Flail spreader
- V-box rear unload broadcast spreader
- Tanker spreaders (two types)

Demand continues for larger capacity and faster equipment to haul and more uniformly spread solid, semi-solid, slurry, and liquid wastes at an optimum time of year. These demands and a growing need for field spreading at sites more distant from the waste production source add to hauling and spreading concerns and influence individual equipment selection.

Decisions about spreading equipment size or type depend on cost, amount and consistency of waste to be handled, haul distances, available spreading time, size of available tractor or truck power and braking, facility door or gate opening sizes, loading height limits, equipment warranty and service, and desired options (splash covers, type of power drive, wheel type, and tire size).

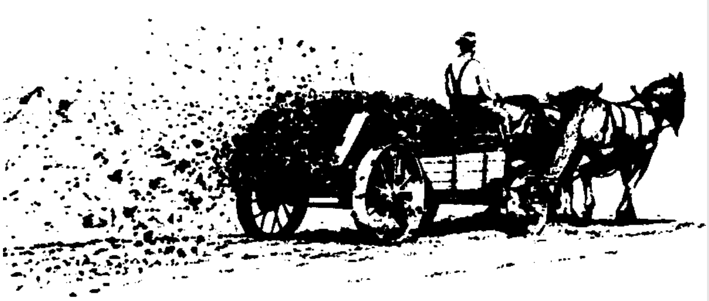
Renting or leasing of hauling, pumping, and spreading equipment can be advantageous for a few days use per year. This affords a way to try different equipment and to maximize the use of limited operating capital. Rental costs can be competitive to annual costs for private ownership of limited-use equipment when all aspects are considered. Another option is to share hauling and spreading equipment with a nearby operator. Compatibility and condition of shared equipment and competition for its use by others are considerations.

Hiring a contractor, commonly called a custom operator, to load, haul, pump, and spread waste is common. Although relatively high cost, the job gets done in a short time. Custom operators, however, generally seek payment based on the number of loads, the weight, or the gallons hauled and spread. The intensive skilled use of relatively high quality equipment by professionals can lead people to the false assumption that they can operate the equipment themselves to save time and money. This could lead to equipment, labor, and timeliness problems and poor use of waste.

(1) Box spreader

The traditional rear-unload box spreader remains popular for hauling and spreading semi-solid and solid waste (fig. 12–80). This equipment requires a relatively low investment and is simple to use. For frequent waste cleanup of small areas and small to average-size operations, hauling and spreading waste in a towed box spreader as a solid material is relatively more convenient and practical than pumping or irrigating the waste. Hitching and filling a box spreader involves less equipment and expertise to organize and operate than does agitation, connecting pipelines, pumping, and using an irrigator. This convenience can affect waste utilization as well as sanitation and appearance of facilities.

Figure 12–80 Box spreader (courtesy Gehl Company)



The load capacity of tractor-tow and truck-mounted box spreader models ranges from about 20 to more than 400 cubic feet. The ASAE Standard S324.1, Volumetric Capacity of Box Type Manure Spreaders (ASAE [f] 1990), is used by manufacturers to provide uniform load capacity ratings (in cubic feet) of different box spreader models. Some advertising materials, however, use bushels, gallons, or tons. See Conversion Factors and Tables of this handbook.

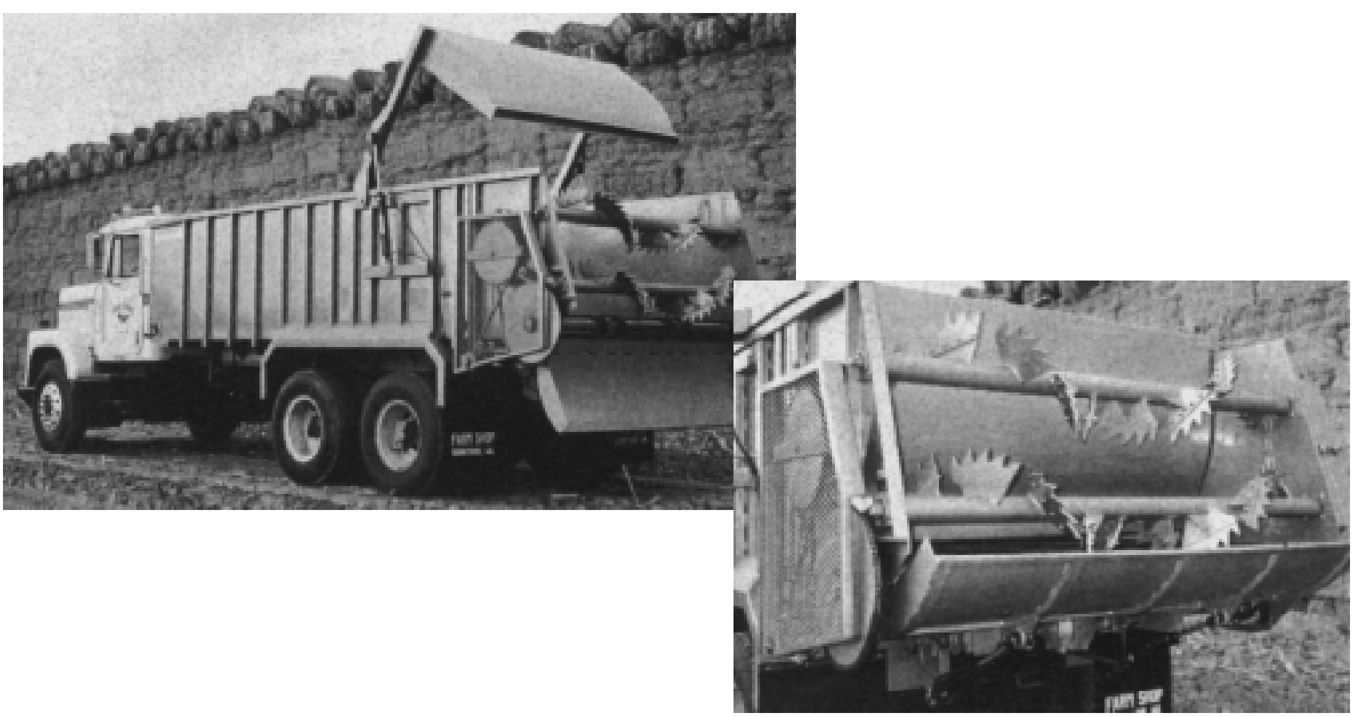
The box spreader's hydraulic-powered push-end gate unload, beater pan cover, and inward-curved front and side extensions aid cleaner hauling and more uniform spreading of slurry and semi-solid wastes.

Box spreaders are available in waterproof or pressure-preservative treated wood or in corrosion resistant or treated steel. A polyvinyl plastic plank or glass fiber-sheeted box interior liner aids unloading; however, plastic materials are not durable in some applications.

Tractor front-end loader damage to a spreader box is a problem in addition to rusting and rotting. Such deterioration and other repair are minimized by careful use, regular cleanup, lubrication, and shelter from weather.

While European studies continue (Malzeryd 1991, Wetterberg 1992), most of the development of spreader-beater design in the United States has come from field experience. The high/low rear beater configuration on box spreaders that is used to loosen solid waste and move it onto a rotating-spiral distributor beater has given way to a simpler rear shredder that is larger in diameter and has a widespread combination beater. The high/low beater configuration remains popular for large capacity, truck-mounted box spreaders, but the spreading uniformity is not always achieved (fig. 12–81).

Figure 12–81 Truck mounted box spreader (courtesy Farm Shop, Inc.)

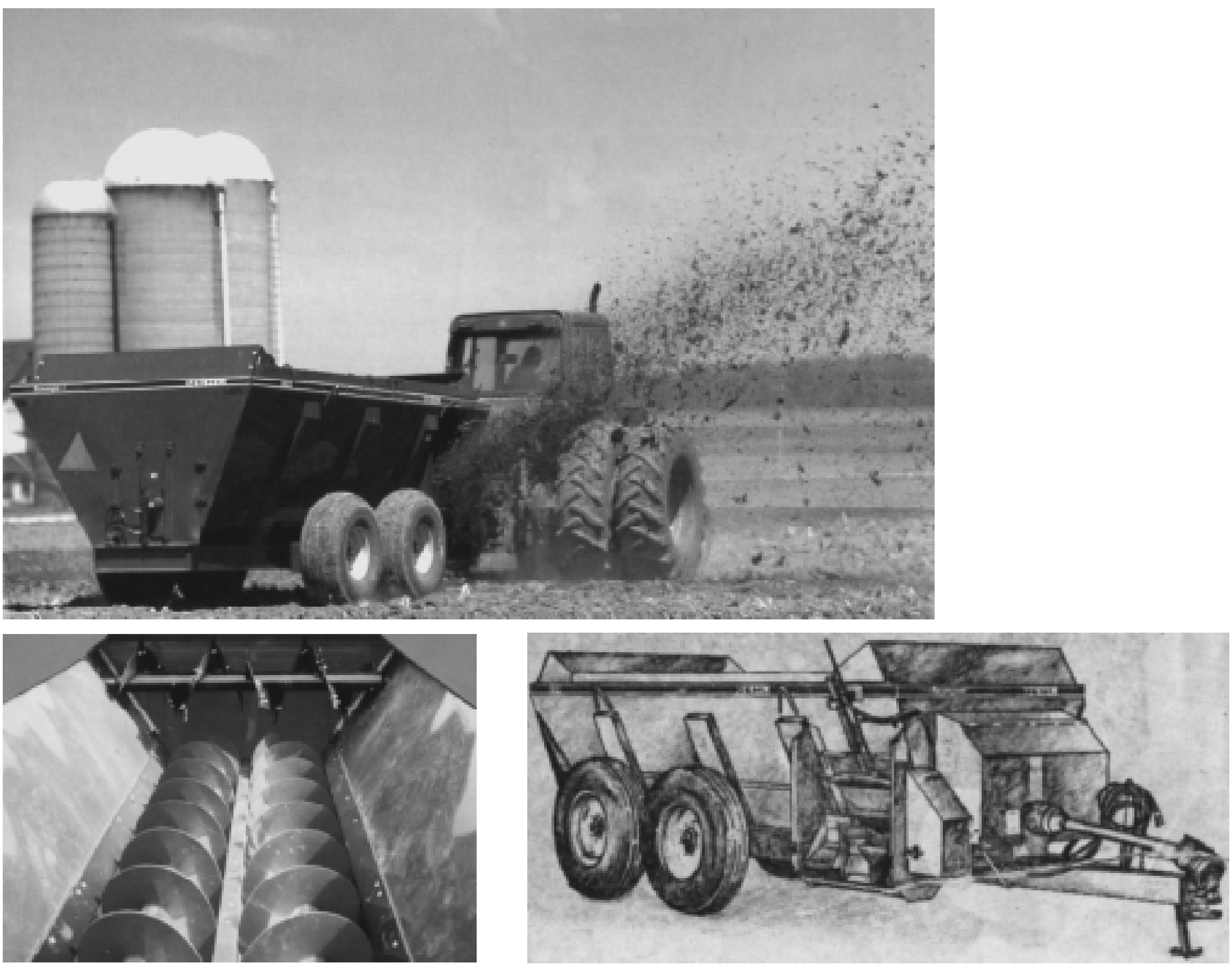


(2) V-box bottom spreader

The V-box bottom, rear unload spreader has been used for years to broadcast dry, bulk, granular fertilizer (see fig. 12–85). In recent years its designed has been combined with construction features of the flail and the box spreader so that it is now used to haul and spread solid, semi-solid, or slurry wastes. This relatively new spreader design is referred to as a side-delivery, slinger, or V-box spreader (fig. 12–82). Models that have a 200- to 500-cubic-foot heaped capacity require a tractor with at least a 60-horsepower motor to operate. Auger-out (rather than chain-apron) unload breaks up and mixes the waste that is then spread with a high speed side or rear mounted beater or slinger.

The tight, V-box bottom has minimum leakage, and the waste that is broken up and unloaded using an auger is more uniformly spread in a wide swath. Besides the spreader design, however, uniform spreading depends on the waste consistency, spreader operation, and spreading conditions. Investment for the V-box bottom spreader with auger unload design and its operating power needs is higher than that for the box spreader.

Figure 12–82 V-box bottom, side, or rear slinger spreader (courtesy of Gehl Company and H & S Manufacturing)

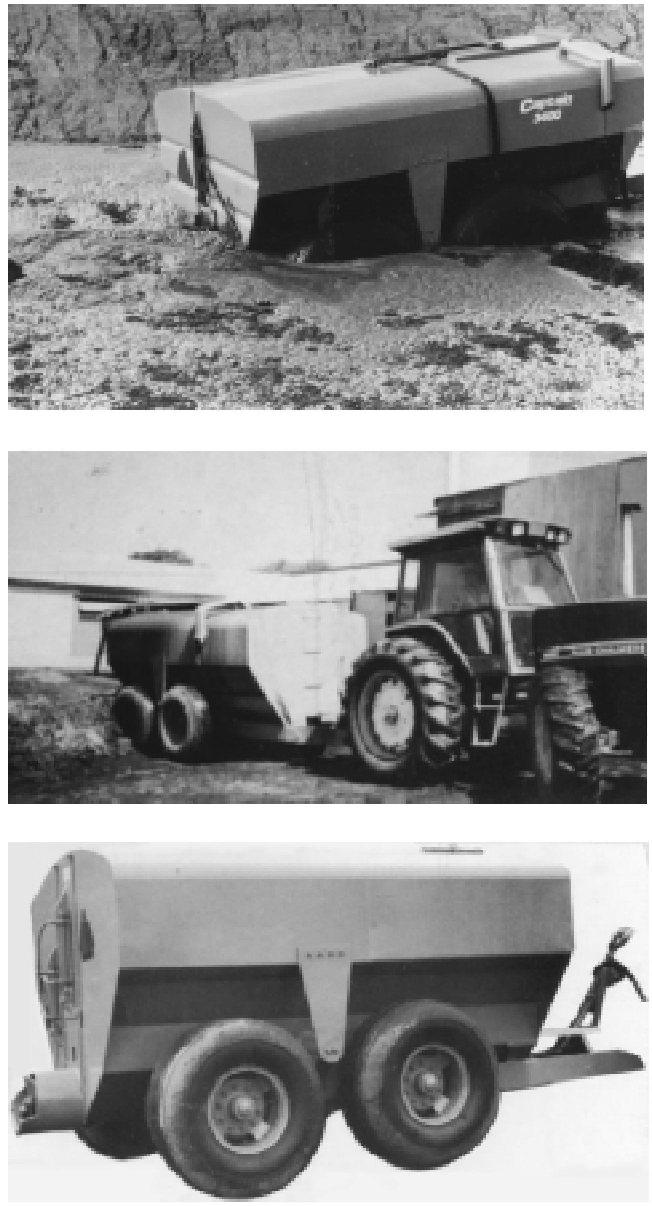


The flail spreader (fig. 12–83) is used for hauling and spreading slurry waste that is solid, frozen, chunky, or heavily bedded (Bartok 1994). This equipment is open top and unloads from the side. Its horizontal metal tank has an adjustable top and a tight bottom. The tank is generally 4 to 6 feet in diameter and varies in length. It is mounted on a sturdy running gear. A strong, PTO-powered shaft with 3-foot-long chains attached about every 6 inches is centrally mounted parallel to the tank length. When operated, the rotating shaft slings the waste out the top of the tank. The spreading rate is controlled by adjusting the top opening and the travel and PTO speeds. Available models have heaped capacity of 170 to 240 cubic feet and require a 60- to 90-horsepower motor to operate. The ASAE Standard S325.1, Volumetric Capacity of Open Tank Type Manure Spreaders, is used for uniform measurement and rating capacity in cubic feet (ASAE [g] 1990). Flail spreader use has slowed with the increased use of liquid and slurry waste handling. The limited load size, high power need, and wind problems when spreading are factors.

Different PTO-powered conveyor, self-loading wagon spreaders have been developed for solid, semi-solid, or slurry waste loading, hauling, and spreading (fig. 12–84). This equipment eliminates the investment and operation labor for a separate loader. The self-loading type spreader has specialized use, relatively high investment, and limited load-carrying capacity.

Figure 12–83 Flail type side unload spreader (Bartok 1994) (courtesy Ideal Industries Inc.)

Figure 12–84 Conveyor self-loading waste spreader (courtesy Jerry's Iron Works)



The V-bottom rear unload broadcast spreader remains popular for dry bulk commercial fertilizer application (fig. 12–85). The spreader is generally mounted on a truck. It is powered by a variable-speed hydraulic motor and uses a chain-apron unload and a high-speed horizontal rotating disc. The disc is designed for light, accurate spreading of dry granular material over a wide swath. An optional slinger/thrower attachment is available for some models. This attachment is used to spread solid fibrous material out about 100 feet (with the wind) onto steep side slopes, such as along roadways.

Figure 12–85 V-bottom rear-unload broadcast spreader (courtesy of Denair Trailer Company)

A hydraulic-lift dump box truck designed to haul gravel and grain is also useful to haul feedyard poultry litter and other solid waste (fig. 12–86). These alternative uses should be considered in selecting hauling and spreading equipment. The dump box capacity typically ranges from 4 to 12 cubic yards. Actual weight or volume of waste hauled depends on the waste characteristics and the dump box design. Spillage problems are minimized if the load is correctly trimmed, wetted down, or covered.

A dump box truck can safely transport large loads relatively quickly over several miles, night or day, and then dump the load. A prompt return for another load keeps the waste transfer equipment working efficiently with relatively few haulers. A tractor front-end loader can spread the dumped waste around the dump site, or used to reload a box spreader for spreading at the desired location.

Elevating-type earthmovers can scrape, load, haul, and spread solid waste from large open areas, such as cattle feedlots, in one operation. See section 651.1203(h) for more information. This equipment is efficient for relatively short hauls, and compaction of the field is minimized. Weather conditions, equipment availability, operator expertise, spillage, noise, safety, and travel routes and distances are considerations.

Figure 12–86 Dump box truck solid waste hauling

(3) Separate pump or vacuum load tanker spreaders

Two types of tanker spreaders are commonly used for hauling and field spreading semi-solid, slurry, and liquid wastes. These spreaders look alike, but operate differently.

The spreader tanker is an enclosed tank mounted on a wagon or a truck running gear. It requires a separate pump for loading the waste (fig. 12–87, see figs. 9–6 and 9–8). The separate pump load tankers are available in 1,000- to 9,500-gallon capacity models. The guide for uniform tanker capacity rating (in gallons) among manufacturers is the ASAE Standard S326.1, Volumetric Capacity of Closed Tank Type Manure Spreaders (ASAE [h] 1993).

Options, such as tanker agitation, inside tank access, wheel arrangement and size, injector spreader distributor, and other accessories, can increase the investment cost for this equipment. A sight-glass on the tanker, for example, permits ready observation of the tanker content during filling and emptying. A PTO or hydraulic motor powered recirculating pump or floor auger may be used to continually agitate the contents, which would aid in more uniform spreading, especially with injector spreading. Some models use a spreader discharge located at the top-rear of the tanker. This discharge is supplied by the tanker agitation pump to assist with a wider broadcast spread. This arrangement also minimizes dripping and accidental tank unload. Interior tank access for loading, cleaning, and repair through a top hatch door is simplest; however an end door has minimum hazard for inside air and gas ventilation and is more convenient for repairs.

Figure 12–87 Separate pump load tanker spreader (courtesy Badger Northland, Inc.)

The second type of tanker used to haul and spread slurry and liquid wastes includes an integral PTO or hydraulic motor powered air-vacuum pump for loading and unloading (fig. 12–88). For more information on this type pump, see sections 651.1203(l) and 651.1206(b)(1)(iv). The addition of this pump makes an "all-in-one" unit. To load the tanker, the vacuum pump empties air down to a pre-set level out of the airtight tank. A transfer hose is then inserted in the stored waste, the load valve is opened, and the waste is drawn up into the tank. The hose is 4 to 6 inches in diameter and 25 feet long. It is made of hard rubber and is relatively stiff. A loading rate at about 200 to 300 gallons per minute is limited to a vertical lift of no more than 12 feet.

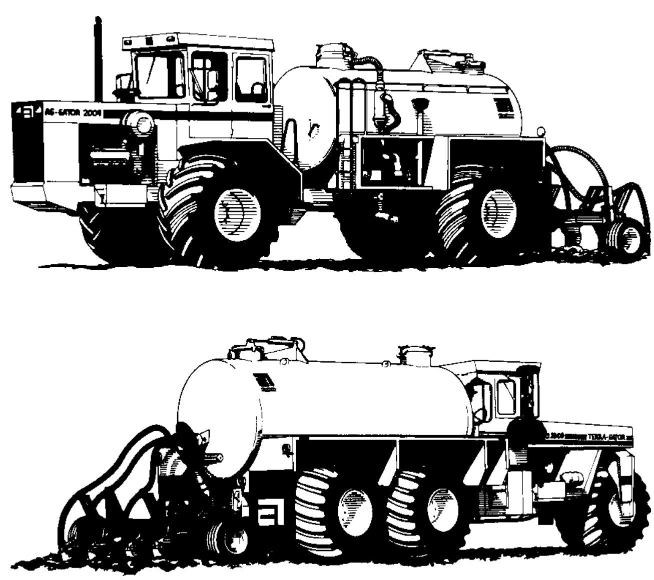
The vacuum tanker is used to agitate stored liquid waste by first loading the tanker, then switching the vacuum pump to pressure mode, pressurizing, and then unloading the full tanker load back into the storage. Tanker capacity and size, running gear options, and spreading aids are similar to those of the pump load spreader tanker.

Self-propelled tanker spreaders that have large floatation tires are designed to haul large loads for several miles or to use on soft soil (fig.12–89). Most of these tankers have self-contained, high-capacity vacuum pumps and extra options that are not available with towed tanker models. Sizes range from a 2,000- to more than a 4,000-gallon capacity with advertised spreading rates of about 15,000 gallons per hour with reasonable loading and haul conditions. Operator comfort, control, safety, and day or night operation are favorable features. Year-around use, such as that done by custom operators, can justify the needed investment.

Broadcast spreading waste from either tanker spreader can use a gravity baffle or splash plate or a powered rotating distributor (fig. 12–90). Models that use tanker pump agitation pump contents up and spread them from the top rear of the tanker, which allows more uniform spreading. The agitation pump is generally located under the tanker rear outlet. A hand or hydraulic-operated gate valve is adjusted open to empty the tank. Soil injection spreading is done with either tanker as explained in section 651.1207(b).

Figure 12–88 Tanker with PTO vacuum pump hose loading (courtesy Clay Equipment Corp.)

Figure 12–89 Self-propelled tanker spreader (courtesy Ag Chem Equipment)



Uniform spreading by gravity flow out of a tanker is difficult. The solids can partly block the tank discharge or less waste will flow as the waste depth in the tank decreases. Also, as the load lessens, travel-speed changes. European engineers have developed an electronic flow control interlocked with a ground-speed monitor (fig. 12–91) that automatically adjusts tanker unload flow according to a preset outlet valve pressure (Carlson 1991, Malzeryd 1991).

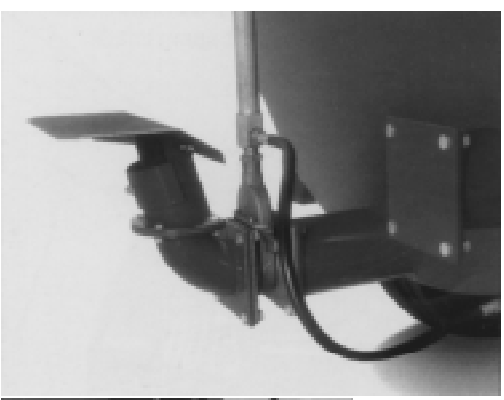
Additional safety precautions need to be taken in the operation of tractor towed tanker spreaders (fig. 12–92). Safety hazards are related to limited operator view, relatively slow speed, heavy braking needs, and potential for overturn and spillage. A super loaded towed tanker that hauls about 5,000 gallons, 667 cubic feet, or 20 tons of waste commands handling expertise and about 150 horsepower to safely operate. Table 12–l0 provides recommendations for spreader capacity and power need.

Table 12–10 Approximate waste spreader and tractor sizes (NE Dairy 1977)*

Box spreader heaped capacity (ft^3)	Min. tractor horsepower	Tanker capacity (gal)	Min. tractor horsepower
150	40	800	60
200	60	1,000	75
250	75	1,500	80
310	85	2,250	90
390	100	3,250	100
470	130	4,000	—

* Towed load should not exceed 1.5 times tractor weight.

Figure 12–90 Baffle plate distributor on tanker spreaders (courtesy J-Star Industries and Badger Northland, Inc.)



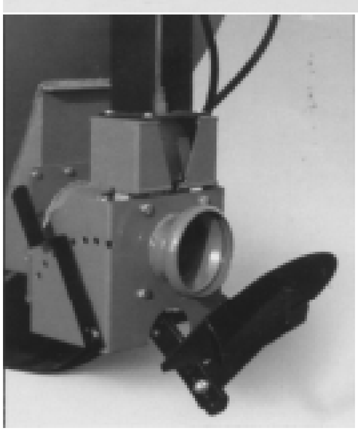
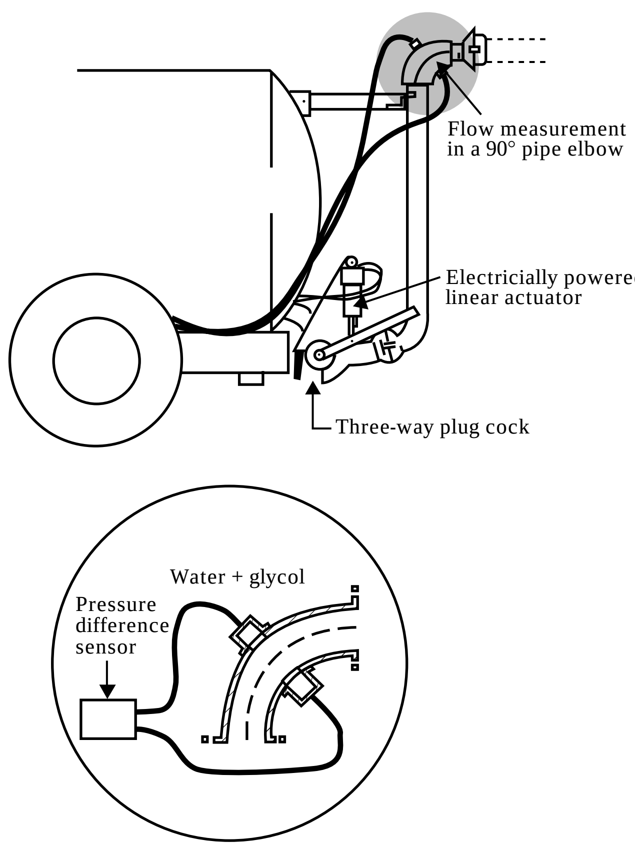


Figure 12–91 Tanker unload uniform discharge control (Carlson 1991)



Tractor power can fail going up a steep slope, or steering control can be lost going downhill. A general rule is that a towed load should not be more than 1.5 times the tractor weight. A 3,000-gallon loaded tanker can weigh more than twice a 100 deadweight brake horsepower tractor that has a ballasted weight of about 14,000 pounds. This is beyond the guideline of ASAE Standard S318.10 for equipment without brakes (ASAE [e] 1995). A surge trailer brake is designed for forward motion and may not function if the tractor power fails going uphill.

Although adequate tractor power is available, soil compaction is a major problem with large towed tanker spreaders. Depending on the design, up to 10 tons per axle is not uncommon. Large diameter wheels with wide tires improve tanker flotation. A single axle with large wheels is used on small models to minimize cost. Walking tandem axles are common with larger (>1,350 gallon) tankers. They aid load distribution and a smoother and faster ride; however, sharp turns cause extreme axle stress. Despite higher cost, triple axle (front axle only or front-and-rear steer) and flotation type tire or track support designs are being adapted on large tankers (see figs. 12–87, 12–89). Dual wheel use on towed tankers has waned because of the added equipment width, axle stress, and extra rolling resistance over rough fields and soft soils.

Routine cleanout and inside repair and maintenance access are necessary. Twine, stones, plastic, and wood pieces sometimes plug tanker pipes and openings. For safety reasons, a forced fresh air supply into the tank and a second person nearby are urged when working inside a tankwagon with only a top opening. See sections 651.1008 and 651.1208 for further information.

Overall construction strength is critical for a tanker spreader, especially where it has attached soil injector spreading. Generally, 1/4-inch-thick corrosion resistant plate steel (painted) is used to construct the tank. As vacuum tanker spreaders age and corrode, too high of an evacuation of the tank can cause an end or side to collapse inward if the evacuation overload control device malfunctions. Regular maintenance, cleanup after use, and covered storage extends tanker life and increases trade-in value.

Vacuum pumps, moisture traps, pipe couplers, tires, and power shafts need regular attention. Shops that specialize in tanker repair report that a vacuum tanker regularly used for swine waste typically has about a 10-year life. The pump and running gear frequently outlast the tank, although adjustable wheel types (for different row crop spacings) and broken wheel spindles have been problems. Pump seals, vanes, and valves may need replacement depending on regular maintenance.

To hasten hauling and spreading liquid or slurry waste to distant fields, a semi-trailer nurse tanker is used to haul waste from storage to a smaller tanker or tractor towed field injector (see fig. 12–89) (Maschhoff 1985).

Figure 12–92 High pressure centrifugal pump (courtesy Cornell Pump Company)

(b) Soil injection waste spreading equipment

Injecting (also called knifing or chiseling) liquid and slurry waste 3 inches or more into the soil minimizes odor and nutrient losses (Goodrich 1993). Nitrogen loss is significant within 4 to 6 hours after broadcast surface spreading. Section 651.1105(a) gives more detailed information on this loss. Injection is necessary, for example, when a nitrification inhibitor is added for N loss reduction of waste or when anhydrous ammonia is added to waste to enhance the N content and better suit crop needs (Sutton et al. 1983).

Traditional injector spreader equipment can be used on a tanker sprader or directly injected with tractor mounted toolbar equipment when waste is pumped to the field. A tanker needs the framework constructed for the twisting, bending loads from the attached injectors. Typically two to six injectors are mounted at the rear of a tanker about 2 feet apart. Mounting the injectors at the front of the tanker or on a toolbar attached on the tractor pulling the tanker aids depth control, traction, and the operator's view. However, this arrangement interferes with hitching and maneuvering. Also, the pressure of the tractor wheels on the injected soil forces out some of the injected waste, which defeats the purpose of injection. Staggered injector shanks reduce trash plugging, and injector shanks that swivel can make short turns. Some models use adjustable injector depth gage wheels. Most use hydraulic lift to raise or lower the injectors.

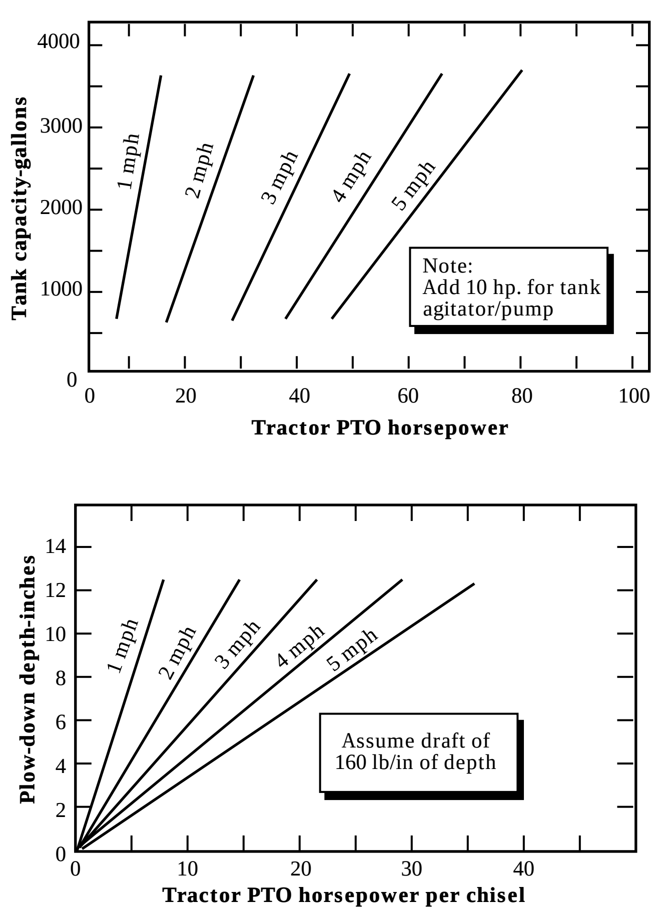
When directly injecting, a 5- to 6-inch diameter soft hose connected between the pipeline and the field spreading hose, which is 4 to 5 inches in diameter (fig. 12–94), aids flexing and reduces pumping friction. About 40 acres are covered at one hose setting. A strong, durable hose is needed to withstand the rubbing and turning friction. Attaching the field spreading hose to a distributor manifold that has a leakproof swivel head on the injector equipment assists turning at field ends, which is difficult with pressurized flowing pumped waste and injectors in the soil. An empty hose rolls and twists on turns. From 4 to 6 injector shanks generally are used for a 6- to 10-foot spreading width, but wider units are available that reduce the spreading rate and travel speed.

The soil surface moisture, field topography, and travel speed affect the power needed to pull a loaded tanker. Injector load is also a consideration and is affected by injector design and operating depth. Figure 12–93 can help to estimate power needs. For example, to pull a loaded 3,000-gallon tanker with four injectors running 4 inches deep in plowed soil at 3 miles per hour would require 80 horsepower [42 + 10 + (7 x 4)]. A Purdue University study determined an additional 18 horsepower per 8-inch deep chisel injector was needed at 4 miles per hour. The added power and injector ownership costs were more than offset by the reduced N volatilization loss (Dickey 1978).

The operation of a pumped waste, tractor towed, hose injector is comparable to that of the traveling gun irrigator. Stored waste agitation, pumping, pipeline, and field hose use are similar. The constant moving tractor with injector spreading, however, needs constant management. The 800 to 1,400 gallons per minute waste pumping rate to the injectors needs to be suited to the number of injectors, field travel speed, and soil nutrient needs. Another tractor and operator at the midpoint of the field is needed to regularly play out the 4- to 5-inch diameter by 660-foot-long hose full of moving, pressurized waste and keep it aligned with the injector spreader as it travels back and forth in the field. Equipment and labor organization, coordination, and operation are essential.

Over-application of waste, especially with vertical knife injectors running 8 to 14 inches deep, allows liquid to ooze out and up and then run downhill. Large rocks and hard soils hamper injector depth control, especially where wide blades are used. In loose soil with few stones, shallow-running 1- to 2-foot-wide sweep injector shovels distribute waste out more evenly and use less power.

Figure 12–93 Approximate power for tanker and per injector (FIS 1974)



Disc injector equipment (fig. 12–95) was developed to improve distribution and waste coverage and to reduce power. Rather than a sweep shovel or knife injector, one design uses a gang of convex, fluted-edge disc blades that rotate horizontally under the (soft) soil surface. The waste is injected under the blades as they are pulled along. The blades are 2 feet in diameter. Another design uses two convex disc blades mounted vertically and slightly angled to the travel direction. The waste is covered as it is injected into relatively soft soils.

The effect on crop residue and conservation tillage where wastes are injection spread should be considered. University of Minnesota engineers are studying injector equipment for more uniform waste application (Goodrich 1993). European research has found covering and soil mixing advantages where double press wheels are run behind injector spreaders used in moist sod. Some European countries require municipal sludge be injected when spread, so injecting in sod is common (Warner 1988). Additionally, some European countries require injection of manure to control ammonia emissions. Innovative injection techniques successfully inject slurry to a depth of 2 inches or less with minimum power requirements (Hujsmans 1994).

Figure 12–94 Tractor towed hose injector spreader (courtesy Hydro Engineering and Dr. P. Goodrich, Univ. of MN)

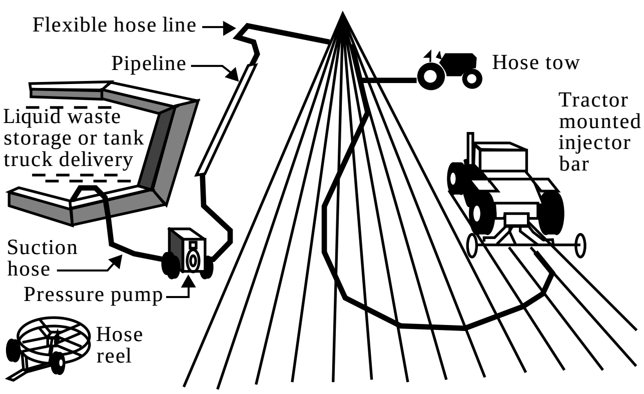
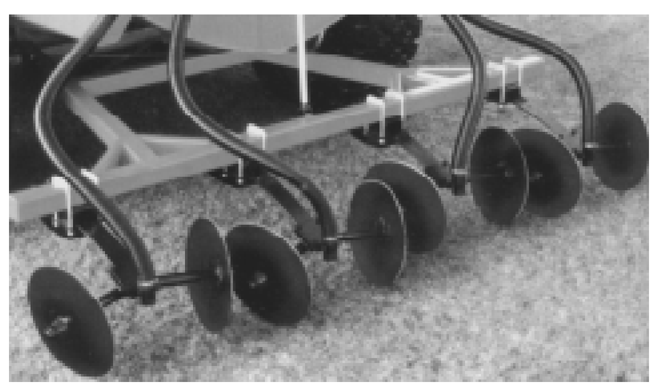


Figure 12–95 Vertical disc covers for injected waste (courtesy J. Houle & Fils Co.)



(c) Pumped waste spreading

Section 651.1206(b) explains characteristics of pumps and pipe used for waste transfer. Slurry waste with up to 10 percent solids can be pumped through a pipeline for several miles to storage or field spreading via gated pipe, irrigator, or towed injector. Less than 10 percent solids is preferred. Agitation before and during pumping is essential to break up and keep solids suspended. Solids sedimentation in low areas of the pipeline and irrigator nozzle clogging are problems. Chopper agitator pump action and a grinder attachment on the high capacity centrifugal pump can break apart and help suspend solids to move through the pipeline and irrigator. Dilution may be required. See sections 651.1102(c) and 651.1205(a) for more information.

Pumped waste spreading via irrigation is increasing in popularity, especially with operations that spread over a million gallons per year. Pumping minimizes soil compaction and labor and spreading equipment needs. Equipment adaptations continue. For example, gated polyethylene pipe is used to reduce labor, investment cost, and operating power. Also, irrigator low pressure drop nozzles are used to reduce waste spreading odor. More developments are expected as demand grows for pumping equipment to spread waste farther away from storage and to minimize odor complaints.

Wind affects uniform sprinkler spreading and may cause odor complaints from several miles away. With adequate storage, pumped slurry waste spreading (in quantity) is typically done in the spring or fall. Cropland is available during this time, and the seasonal competition for the labor needed for equipment setup, startup operation, and cleanup is less. The fate of the manure constituents must also be considered.

Different irrigation systems are used to spread agricultural wastes. Major selection factors are summarized in table 12–11.

Table 12–11 Irrigation system selection factors (Patronsky 1978, Shuyler 1973)

Factor	Type of system: Handmove sprinkler	Towline	Sideroll	Travel gun	Center pivot
Effluent solids	Up to 4% solids	Up to 4% solids	Up to 4% solids	Up to 10%	Up to 10%
Operation size	Small	Small to medium	Small to medium	All sizes	All sizes
Labor need	High	Medium	Medium	Medium to low	Low
Initial investment	Low	Low	Medium to high	Medium to high	High
Operation costs	Medium	Medium to high	Medium to high	Medium to high	Medium to high
Expansion	Purchase more pipe and equipment	Purchase more pipe and equipment	Purchase more pipe and equipment	Purchase more pipe and equipment	Purchase more pipe and equipment
Hourly attention	Medium	Medium	Medium	Medium	Low
Soil type	Suitable to wide range of intake rates	Suitable to wide range of intake rates	Suitable to wide range of intake rates	Suitable to wide range of intake rates	Suitable to wide range of intake rates
Surface topography	Wide	Wide	Limited	Wide	Wide
Crop height	Adaptable	Low	Low	Adaptable	Adaptable

Two or more power units and pumps can be employed during pumped waste spreading operations. This involves:

- One continuously operating chopper or impeller type agitator pump that is powered by an 80- to over 100-horsepower motor to keep stored solids mixed with liquids (see fig. 12–45).
- One similarly powered unit to operate a high pressure (at least 100 lb/in^2) centrifugal pump (sometimes 2 units) to move 200 to more 800 gallons per minute of slurry to the field (see fig. 12–92).
- One or two power units to operate the irrigation system.

Labor coordination and communication on starting, stopping, and operating the equipment are needed for uniform spreading. Pumps need to be primed, and mixed solids and liquids need to be kept moving to prevent settling and plugging. Pipes need to be rinsed and emptied when irrigation is completed. If this is not done, the retained waste dries or freezes, causing the equipment to plug the next time it is used.

(1) Pipe and pipeline equipment

Pipe size and friction is explained in section 651.1102(c). Small diameter pipe is made from steel, copper, aluminum, or various plastics. Steel, cast iron, plastic, or concrete pipe is used for culverts, drains, and some pipelines. See section 651.1202(b) for more information. Irrigation pipe greater than 2 inches in diameter is generally made from plastic or aluminum because they weigh less. Hard rubber, which resists vacuum pumping suction or load of towing the irrigation equipment, and flexible fabric pipe, which is pressurized, are used with tanker and irrigator connections.

In pumping applications, pipe from storage to field is coupled with ring lock or kamlock couplers and can be attached to a hose at the field using barb fittings and clamps. Most hoses are 4 to 8 inches in diameter. Pressure ratings on these hoses are 100 to 150 pounds per square inch. Drag hose for towed injector spreading is 4.5 to 5 inches in diameter and is rated at 150 pounds per square inch. This pressure rating is needed to withstand towing stresses.

The durability of the pipes varies:

- Aluminum is resistant to corrosion, but is easily dented and bent.
- Plastic pipe loses strength with temperature increase. Some plastics become brittle with exposure to sunlight, or they become stiff in cold weather and break.
- Flexible fabric pipes wear through and leak where excessively rubbed when pulled along the ground or where they are wound and unwound from a spool.

NRCS Conservation Practice Standard, Pipeline, Code 430, ASAE Standards (ASAE [m] 1991), and manufacturers' literature can be consulted for thickness, pressure rating, coupler assembly, and pipe installation requirements.

As liquid flows through a pipe, the liquid drag or friction against the pipewall restricts the flow. Larger diameter pipe with the same internal roughness has lower friction at a given flow rate and uses less pumping energy. However, the initial investment is higher than that required for a smaller pipe. The friction loss for steel and plastic pipe is shown in table 12–12. The loss is based on the diameter of the pipe and is for transport of water. Slurry waste may have as much as 10 percent more pipe friction losses. Section 651.1102(c) has more information on friction loss.

The required pressure to maintain flow is reported in feet (of water) or pounds per square inch. Feet equates to the pressure of a water column of that height (fig. 12–96). A vertical pipe that contains 2.31 feet of water has 1 pound per square inch of pressure at the bottom. Total head, in feet, is converted to pounds per square inch by dividing the feet of head by 2.31. Table 12–12 shows the friction loss in both feet and pounds per square inch. The total drag or friction loss in a pipeline includes pressure losses from pipe length, elbow/reducer fittings, and restrictions (e.g., nozzles). Note in the table the effect that increasing the flow rate has on pressure loss.

At about 2 feet per second velocity, solids settle in low spots along a pipeline. At a velocity more than 5 feet per second, friction loss and water hammer are problems. A velocity of 3 to 6 feet per second is used in pipe diameter selection designs. The velocity of liquid waste in pipes not buried or otherwise anchored in place should be limited to 5 feet per second. Flush pipelines with clean water and disassemble and drain them to remove contents after pumping waste. This helps to avoid problems with plugging.

(2) Surface irrigation equipment

Surface irrigation includes flooding, border, furrow, and gated pipe systems. A maximum land surface slope of 2 percent and a high level of management are required to control runoff and obtain uniform wastewater distribution. The low investment, power, and equipment needs of surface irrigation are the tradeoffs for the high labor. See NRCS Conservation Practice Standard, Irrigation System (Surface and Subsurface), Code 443-1, for more information.

Gated pipe wastewater distribution assists simpler, faster, more uniform wastewater application by gravity (Schnieder et al. 1993). Holes are spaced about 30 to 80 inches apart in 30- to 40-foot lengths of aluminum or plastic pipe that is at least 4 inches in diameter (fig. 12–97). The holes, which are about 2 by 6 inches each, have a sliding cover or gate that is opened or closed by hand. These covers are adjusted for uniform gravity discharge all along the gated pipe.

In operation, liquid waste is transferred from storage to the field and enters the gated pipe through a valve at one end. Lengths of gated pipe are connected together, and the gate openings (usually every second or third one) are adjusted for uniform outflow along the length of gated pipe (table 12–13). Non-uniform solids distribution in the liquid can be troublesome because dissolved nutrients are carried in the liquid. However, larger solids settle in the pipe, or the nutrients are filtered out by grass where wastewater leaves the gated pipe openings. The spreading arrangement and the size of the pipeline and pump should be considered in selecting a gated pipe system.

(3) Handmove sprinkler equipment

Although messy to handle, the handmove sprinkler is used with small wastewater capacity liquid waste spreading. Equipment needs and the initial investment are low, and the equipment is adjustable to fit various sized fields. See NRCS Conservation Practice Standard, Irrigation System (Sprinkler), Code 442-1, for more specific information.

Table 12–12 Friction loss in 100 feet for 3- and 4-inch diameter pipe used to transport water (MWPS 1985)

Gallons per minute	Steel I.D. 3.068" (ft)	Steel I.D. 3.068" (lb/in²)	Plastic I.D. 3.216" (ft)	Plastic I.D. 3.216" (lb/in²)	Steel I.D. 4.026" (ft)	Steel I.D. 4.026" (lb/in²)	Plastic I.D. 4.134" (ft)	Plastic I.D. 4.134" (lb/in²)
40	0.8	0.4	0.3	0.1	0.2	0.1	0.1	0.0
60	1.7	0.7	0.7	0.3	0.5	0.2	0.2	0.1
80	2.9	1.3	1.3	0.5	0.8	0.3	0.4	0.2
100	4.4	1.9	1.9	0.8	1.2	0.5	0.6	0.2
120	6.2	2.7	2.7	1.2	1.7	0.7	0.8	0.3
180	—	—	—	—	3.5	1.5	1.7	0.7
220	—	—	—	—	5.1	2.2	2.4	1.0

Figure 12–96 Total head (ft) equals elevation + pressure + friction

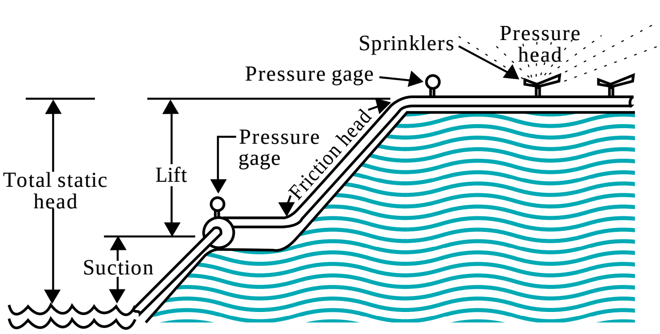


Table 12–13 Maximum recommended flow rate in openings in gated pipe with holes spaced 30 to 40 inches apart (MWPS 1985)

Gallons per minute	Land slope (%)
40	0.2
25	0.4
16	0.6
12	0.8
10	1
5	2

One or more laterals are hand-placed onto a mainline and operated as shown in figure 12–98. Each sprinkler has a capacity between 1 and 20 gallons per minute. The needed pump capacity is the sum of all the operating sprinklers. Lateral sets are assembled from hand-moved sections of pipe that has sprinkler nozzles 30 to 40 feet apart. Each sprinkler then theoretically covers a 60- to 80-foot circle When the laterals are set up and the centrifugal pump is operating, the lateral valve is opened and the system is operated for the required period. The system is then shut off, and the lateral is moved and reset at a new location. The operation is then repeated until completed. An example of this operation:

A 1,320-foot-long (0.25 mile) lateral covers about 1.8 acres. It has 22 sprinklers set 60 feet apart. Each sprinkler spreads about 10 gallons of liquid waste per minute (600 gallons per hour). This amounts to about 0.3 inches per hour on each 60-foot circle. Table 12–14 gives the discharge in gallons per minute for sprinkler nozzles.

Figure 12–97 Gated pipe gravity irrigation (courtesy Armin Plastics Corp.)

(4) Towline sprinkler equipment

The towline sprinkler is assembled and operated similar to the handmove sprinkler except that a tractor is used to move the lateral to the next setting (fig. 12–99). The investment is higher for the towline sprinkler, but labor is lower and the acres per hour covered are more than those with a handmove sprinkler. To avoid damage, a main line buried or placed in a shallow ditch is needed for tractor tow travel back and forth. To resist towing stresses, the lateral has strong couplers between sections. Laterals can be up to 1,320 feet long. The moveable equipment is adaptable to varied field sizes; however, the field shape should conform with the lateral length. The towline sprinkler is best used in rectangular fields and where hayland, pasture, or other low-growing crops are grown. Sod strips are best used for sets in tilled fields.

Table 12–14 Sprinkler nozzle discharge in gallons per minute (MWPS 1985)

Pressure (lb/in^2)	Nozzle diameter (inch) 3/16	1/4	5/16	3/8	1/2	3/4	1	1 1/4
50	7.1	12.9						
60	7.8	14.0	22.0					
70	8.5	15.4	23.9	33.2				
80	9.1	16.4	25.7	35.7	61.6	154	264	416
100	—	—	—	40.7	68.9	173	296	462
120	—	—	—	—	—	189	324	511

Figure 12–99 Towline sprinkler

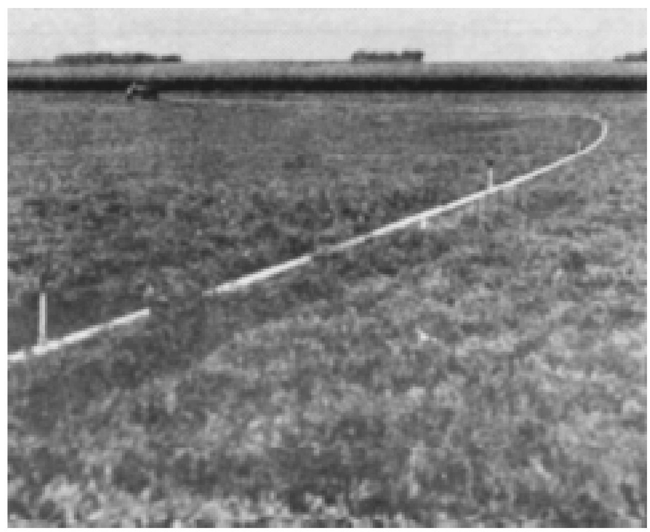
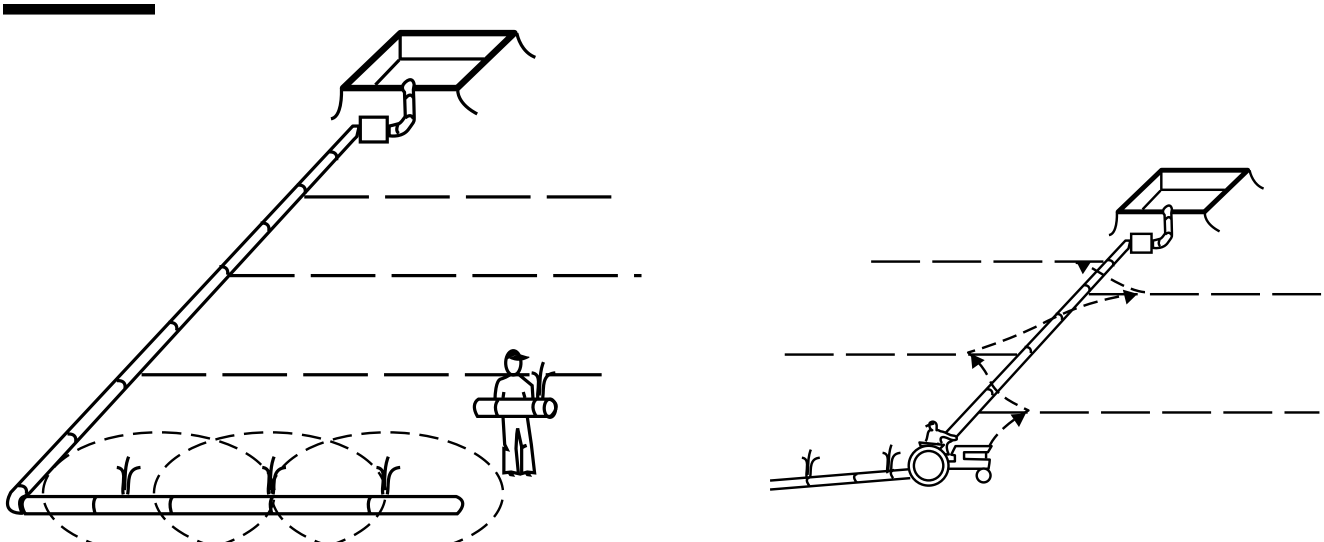


Figure 12–98 Handmove sprinkler



(5) Side-roll sprinkler

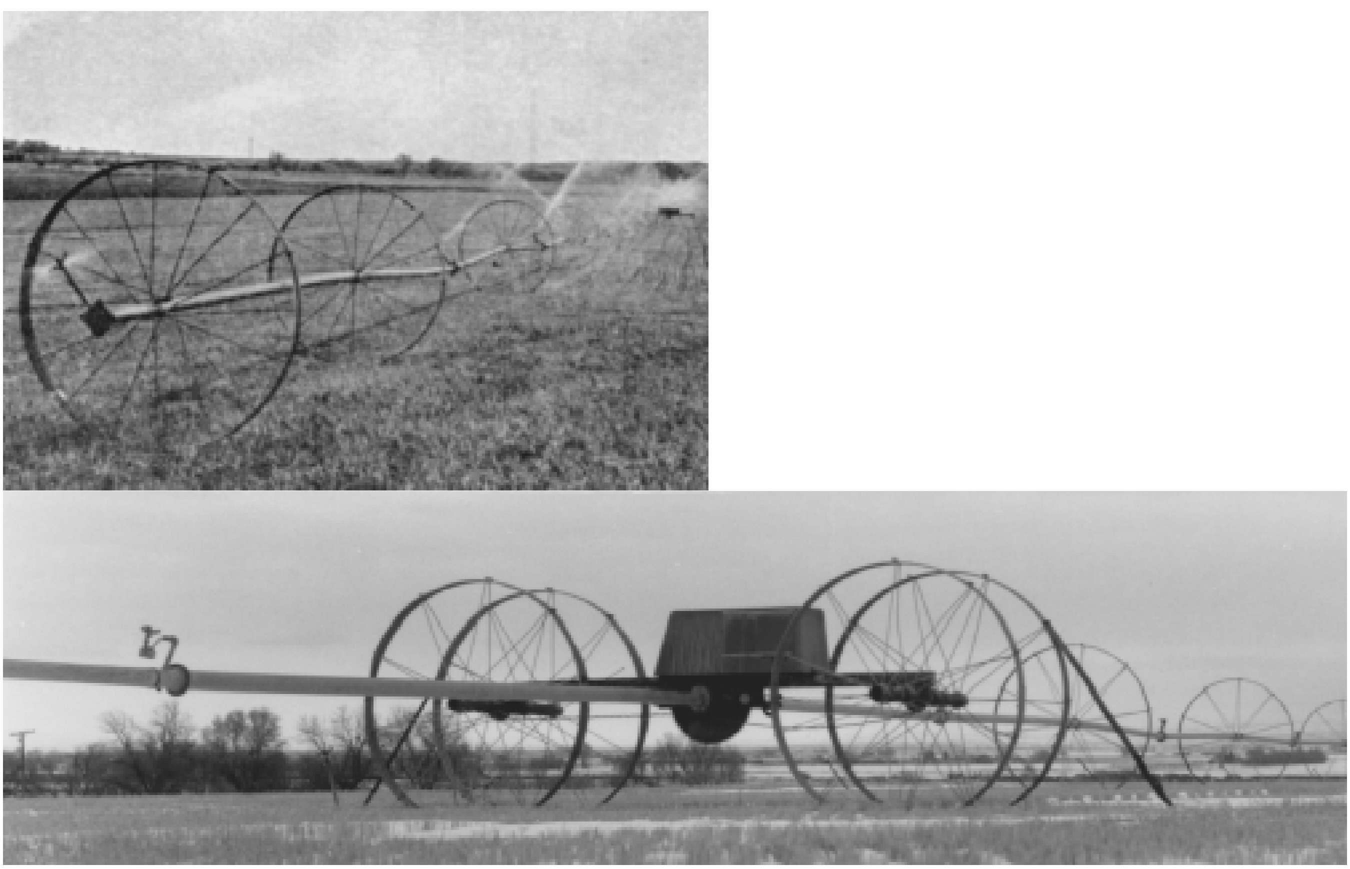
The side-roll sprinkler's operation and the area covered compare to that of the towed sprinkler. The side-roll is moved or rolled in uniform spaced sets along a main line (fig. 12–100). Rather than tractor towed, the side-roll sprinkler has wheels about 4 to 7 feet in diameter on about 30-foot spacings that use the lateral pipe as an axle. A 5- to 20-horsepower engine centrally mounted on the side-roll sprinkler is hand-started every few hours. This engine powers about a 660-foot length of the side-roll. It uses a chain drive to roll the section over to the next set.

The side-roll sprinkler is relatively messy, slow, and requires frequent attention. It is useful with small operations and for low-growing crops. Lateral alignment is a problem on uneven topography. Disassembly or special wheels are needed for moving the side-roll sprinkler to other locations.

(6) Stationary big-gun sprinkler

A stationary big-gun sprinkler is especially applicable with the frequent pumpout of a waste storage pond (<1 million gallons) to different locations (fig. 12–101). The 2- to 4-inch diameter, flexible high-pressure nozzle can pass solids and spread slurry waste over an area that is 100 to 300 feet in diameter (0.2 to 1.5 acres) per setting. The stationary big-gun sprinkler requires a moderate investment, is relatively simple to use, and completes the job quickly. However, it requires more labor than the traveling gun sprinkler and is messy to operate. The capacity and power need are comparable to that of the traveling gun. Some problems that have occurred in using this sprinkler are that it is messy to service, does not apply the waste uniformly, does not spread the waste efficiently in strong wind, and odor complaints are common.

Figure 12–100 Side-roll sprinkler



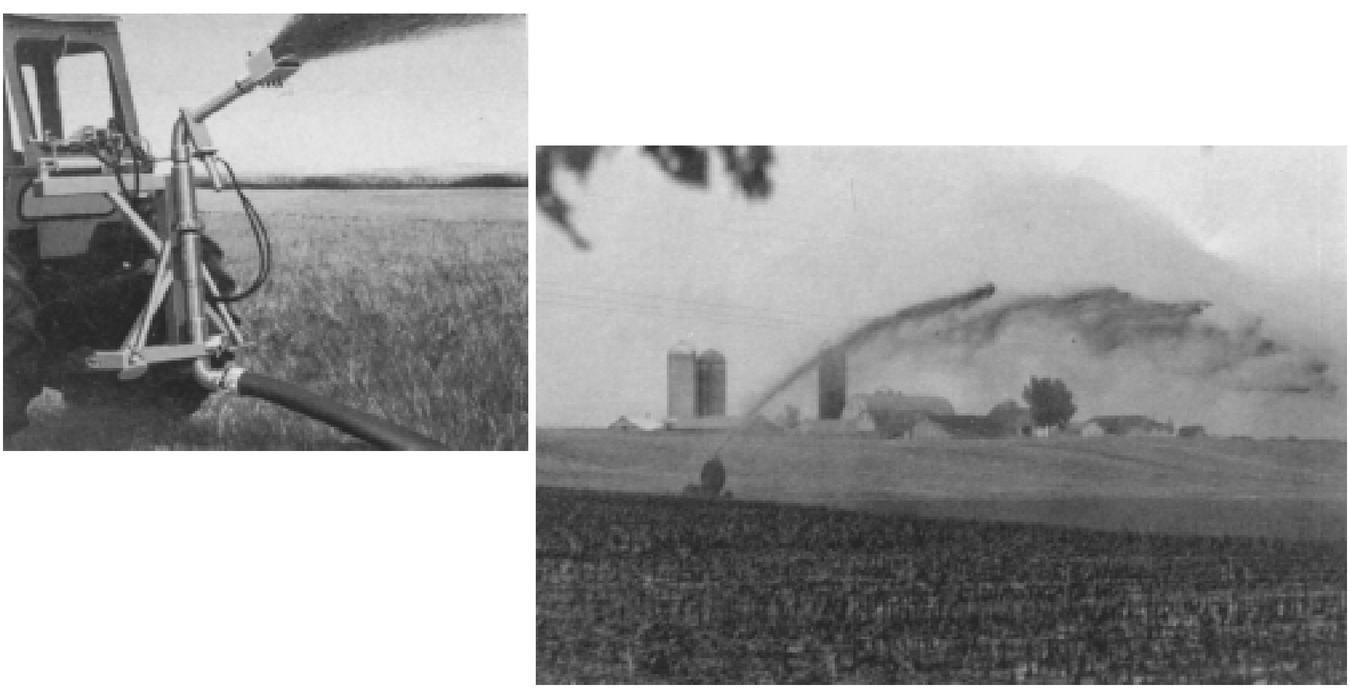
The big-gun sprinkler is generally mounted on a trailer or 3-point hitch and connected to a moveable hose or pipeline that has been laid down in sections from the waste storage. While agitating the stored waste with a chopper agitator or impeller agitator, a high capacity centrifugal pump (see fig. 12–92) pumps the agitated slurry to the big gun. After the desired amount of wastewater application at one set, the high capacity pump is stopped, the big-gun sprinkler is moved (usually with a tractor), and the pipeline is taken up. Then it is reset and the equipment operated at another setting. The uniformity of coverage of a circular or semi-circular area depends on management, the nozzle setting, and the wind.

(7) Traveling gun sprinkler

Traveling gun sprinkler are either cable-tow (soft hose) or hose tow (hard hose) type (fig. 12–102). The cable tow irrigator has a gun sprinkler mounted on a wheel cart or skids to which a soft, collapsible, 4- to 5-inch diameter hose is attached. Before operation, the gun cart, cable, and hose are unreeled across the area to be irrigated. The cable winch end is anchored at the end of the run or lane. Depending on stored waste quality and pumping distance from storage, one or two high capacity centrifugal pumps feed the irrigator from the agitated waste storage. During operation, the cable is slowly rewound by an auxiliary engine, water motor, water piston, or turbine driven winch that tows the irrigator. Most cable tow irrigators that have auxiliary power can be used to apply liquid and slurry wastes, which can plug a water drive sprinkler.

A hose tow traveling gun sprinkler includes a cart or skid mounted sprinkler gun towed along by a 2- to 4-inch diameter hard hose. The hose is attached to a powered, slowly rotating takeup and storage hose reel that is parked at the end of the irrigated lane. Before operation the hose reel is parked at the end of the irrigated lane or run and the hose is unreeled (with the sprinkler gun) to the opposite end. The flexible hard hose supplies the liquid to the sprinkler and also tows it slowly across the field when wound onto the take-up reel. The hose reel is powered by a turbine, bellows, liquid-piston, or auxiliary engine. Solids in the liquid affect liquid-drives as they do with the cable-tow traveling gun sprinkler.

Figure 12–101 Stationary big-gun slurry sprinkler (courtesy Hydro Engineering and J. Houle & Fils, Inc.)

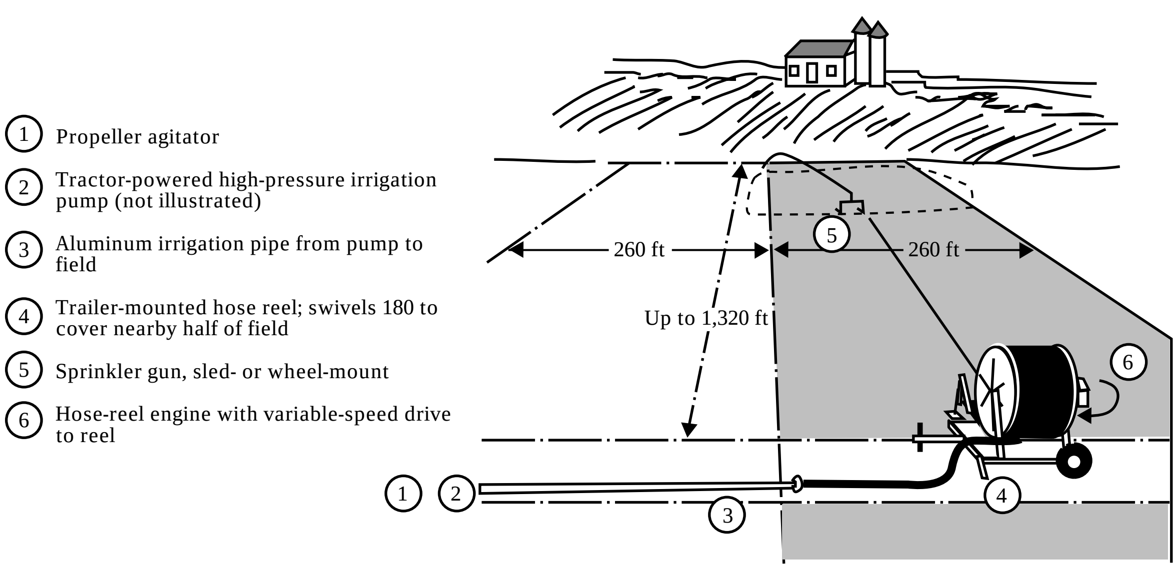


High, low, and multiple sprinkler gun cart designs are available for traveling gun sprinkler. The cart selected depends on crop height and the area to be irrigated. Nozzles are available for irrigating up to a 360-foot swath at more than 1,000 gallons per minute capacity. Table 12–15 gives the nozzle trajectory of a big gun stationary slurry sprinkler. Operating the nozzle in a part-circle pattern permits operating the gun on dry ground. In some models the size, length, and winch of the hose allow for irrigating up to 1,320 feet away from the mainline. The normal spacing between lanes is 60 to 70 percent of the sprinkler wetted diameter.

The hard hose maintains its shape and resists tow wear, but is bulky to handle, stiff to use (especially at freezing temperatures), and hard to store. The soft hose is more convenient to handle and expands slightly when pressurized, which increases the flow capacity. However, hose twisting and wear are problems when handling or moving the hose, which is necessary when resetting the sprinkler.

Depending on the nozzle, a traveling gun can irrigate up to 20 acres per setting. Adjusting the travel speed or nozzle affects the application rate. Different nozzle types, sizes, and capacities are shown in table 12–15. Either a taper bore or a ring bore nozzle is used for a traveling gun sprinkler. The taper bore nozzle is not adjustable, but spreads farther from the mainline than the ring bore nozzle, which can be adjusted. The 24

Figure 12–102 Traveling gun sprinkler with soft and hard hoses (courtesy Tuckasee Irrigation)



degree trajectory is lower than that of the 27 degree and has fewer problems caused by the wind, such as odors. The 27 degree trajectory can clear crops and spread farther out than the 24 degree trajectory.

Relatively popular for pumped waste spreading, the traveling gun irrigator needs minimal labor, has moderate power need, minimizes soil compaction, and can be moved to different fields and used for other irrigation. The relatively high investment, operator expertise, wind distortion, and odor source for a large surrounding area are major concerns. A traveling boom sprinkler that lays down an irrigated swath under low pressure is available and reduces some of these concerns (fig. 12–103). Low pressure traveling booms are subject to plugging.

Table 12–15 Irrigation gun pressure, size, and discharge (MWPS 1985)

	Nozzle trajectory													
	24°								27°					
Taper bore (in)	.6		.7		.9		1.1		1.3		1.5		1.75	
Ring nozzle (in)			.86		1.08		1.26		1.41		1.74		1.93	
(lb/in²)	gal/min	dia	gal/min	dia	gal/min	dia	gal/min	dia	gal/min	dia	gal/min	dia	gal/min	dia
50	74	225	100	250	165	290	255	330						
60	81	240	110	265	182	305	275	345	385	290	515	430	295	470
70	88	250	120	280	197	320	295	360	415	410	555	450	755	495
80	94	260	128	290	210	335	315	375	445	430	590	470	805	515
90	100	270	135	300	223	345	335	390	475	445	626	485	855	535
100	106	280	143	310	235	355	355	400	500	460	660	500	900	550
110	111	290	150	320	247	365	370	410	525	470	695	515	945	565
120		157	330	258	375	385	420	545	480	725	530	985	580	
130								565	485	755	540	1025	590	

Figure 12–103 Traveling boom sprinkler/spreader (courtesy Alfa Laval Agri, Inc.)

(8) Center pivot sprinkler equipment

A center pivot sprinkler propels itself in a full or part circle from a center anchor or pivot point (fig. 12–104). Different sizes spread liquid waste on a few acres to more than 600 acres per setting. Operable over uneven topography, the center pivot sprinkler uses 100 to more than 150 pounds of pressure per square inch to operate. This requires a 30- to 75-horsepower motor, depending on sprinkler size, construction, and nozzle. A pump is also needed for agitation and to transfer waste from storage to the sprinkler.

Drop tube nozzle distribution reduces the power need and odor problems of other nozzles used, but spreading may be uneven because of the variations in pressure. The driving power to slowly move the center pivot can be from the liquid pressure, an electric motor, or an oil or hydraulic drive wheel located at each of the irrigation pipe supports (towers). Variable speed and optional computer programmed control assist uniform application although wind is a problem. If the irrigator is constructed of aluminum, it requires less moving force, weighs less, and is resistant to corrosion. However, the investment is higher than that for a galvanized steel sprinkler.

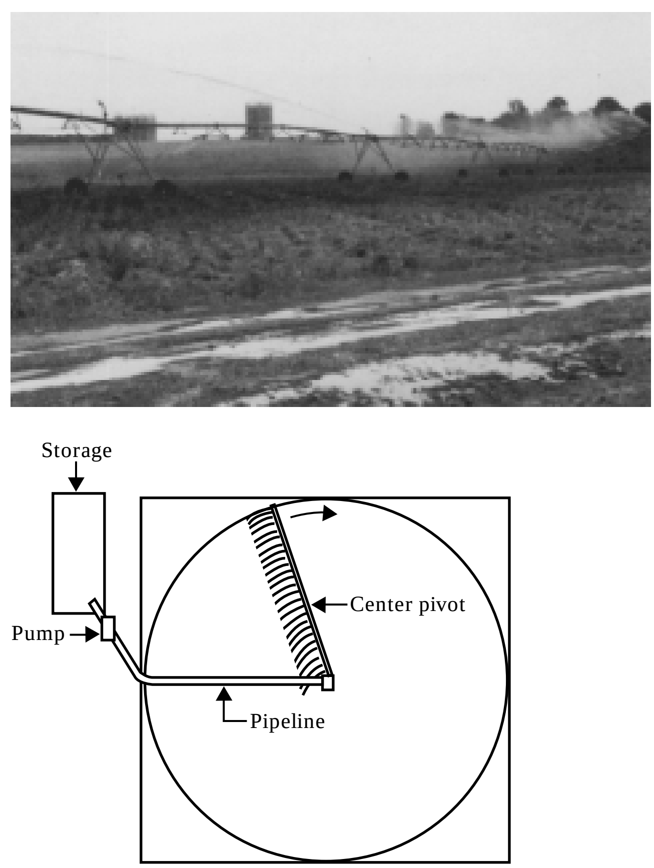
The relatively high investment for a center pivot sprinkler is tempered by its relatively low operating labor and speedy and uniform application. Most models are set up and used at only one location; some can be towed to different locations. Typically, one or more center pivot irrigators are regularly used each season to spread agricultural product processing plant liquid waste on growing crops. The sprinkler generally operates 6 to 10 feet above the ground surface for the most efficient spread and crop clearance, so it is vulnerable to high wind and lightning damage.

(d) Biogas production equipment

As explained in section 651.1006(d), biogas production is the anaerobic bacterial decomposition of organic matter into primarily methane (CH_4) and carbon dioxide (CO_2). Biogas production is well understood from a municipal sewage treatment standpoint and has been successfully done on a commercial basis for many years.

Biogas system management is demanding and critical as optimum temperature, pH, waste quality, loading rate, and related operating conditions are needed for desired bacteria performance. Because biogas is difficult to store, it needs to be used as it is produced. Although small installations are used for intermittent production of relatively small amounts of biogas, most installations focus on a moderate continuous production operation that can involve an array of different equipment. To date packaged biogas models have not been made available, so equipment from varied sources is used. The equipment shown in figure 12–105 is for one moderate-size, pilot model that may become commercially available (Vetter 1993).

Figure 12–104 Center pivot sprinkler (courtesy of Hydro Engineering, Inc.)



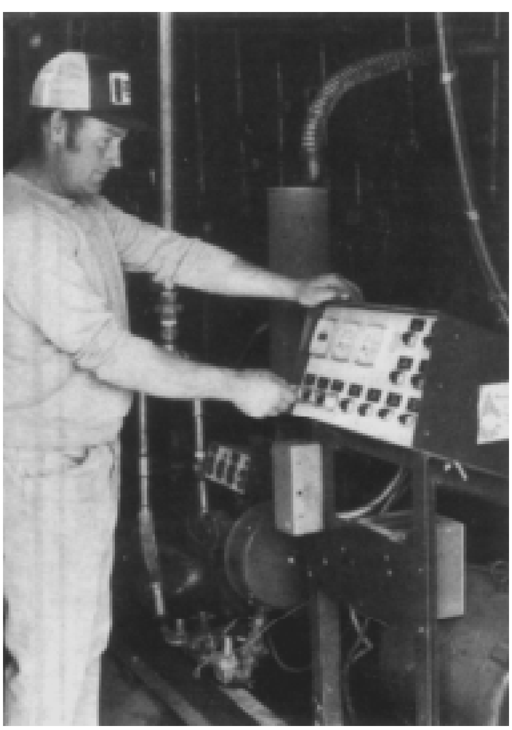
Typical biogas production equipment needs using agricultural waste are identified by Vetter (1990). Figure 12–106 is a schematic of an installation used since 1986 to generate biogas for heating a nursing home. This installation uses waste from a 300-cow dairy. As identified in this figure:

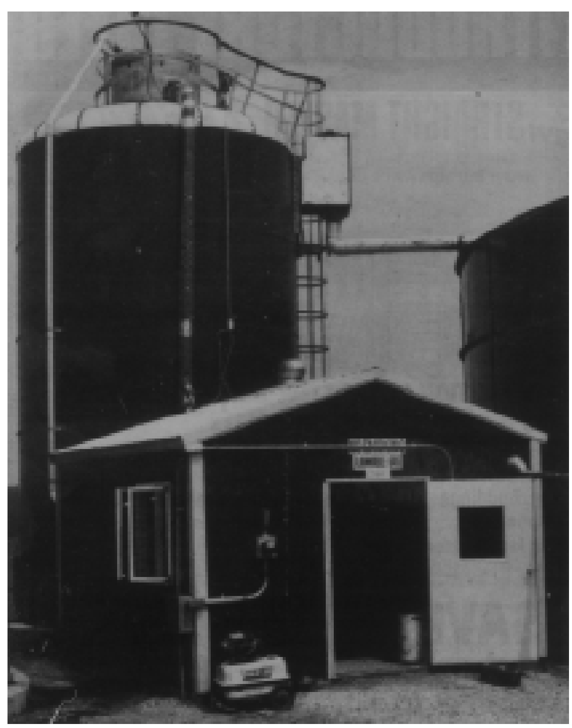
- The solids separator provides a more uniform liquid to aid bacterial action and digestion.
- The two mix pumps ensure that a well mixed supply is available if a pump fails.
- The feed pump intermittently, but regularly, feeds fresh waste into the digester.
- The digester mix pump continually circulates digester contents slowly around the heater to permit uniform heating of waste (also see fig. 10–45).
- The boiler provides the heated water supply to keep the digester contents at 95 °F.
- The scrubbers clean the sulfides from the raw biogas to minimize corrosion as the gas moves to storage and awaits burning for heating water that is circulated around the building.

While biogas is obtained from the digestion process, the liquid effluent and separated solids remain at about the same volume as dilution and cleanup water get added. These liquids and solids factions must be handled with pump, conveyor, and storage equipment similar to those of a waste handling system without a digester.

During the 1970's, several non-commercial digesters of varying designs were constructed on American farms and at different research stations. The installation shown in figure 10–45 illustrates one constructed in 1974 at Pennsylvania Agricultural Experiment Station. It was designed to produce biogas using wastes from 50 to 100 dairy cows. It operated until 1978. The technical requirements and economics of such a system are explained in Agricultural Experiment Station Bulletin 827, Agricultural Anaerobic Digesters (Persson 1979).

Figure 12–105 Biogas production equipment





A comparable digester (fig. 12–107) was constructed in 1976 at the University of Missouri swine research farm. The investment at that time was estimated at $25,000, which did not include much skilled labor. This unit operated until 1986. Its condition at that time along with the design and construction information are in a report by D.M. Sievers (1990).

Rather than operate for a mesophilic bacteria temperature of about 95 degrees Fahrenheit, a simpler low temperature digester operates at 40 to 60 degrees Fahrenheit. While gas production from the micro-organisms that thrive at these lower temperatures is slower and more variable than that for the mesophilic digester, the low temperature digester may have more applications for its use. See section 651.1006(d)(1)(v) for more information.

Figure 12–106 Biogas production equipment layout schematic (Vetter 1990)

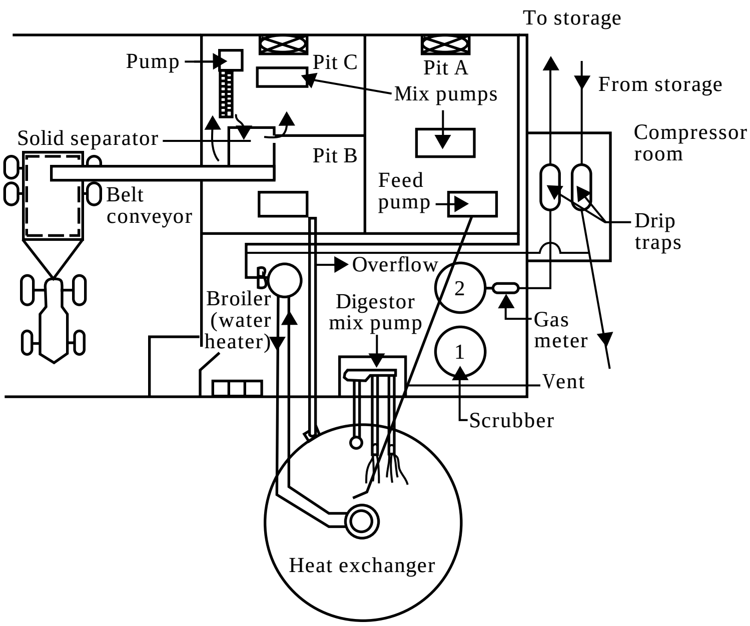
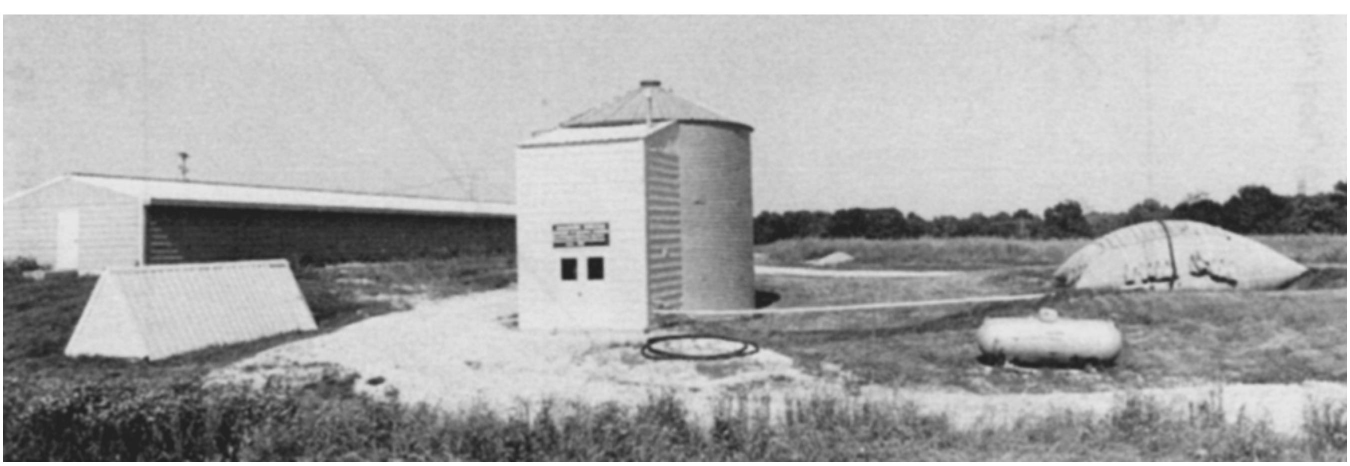


Figure 12–107 Biogas production equipment at the University of Missouri (Sievers 1990)



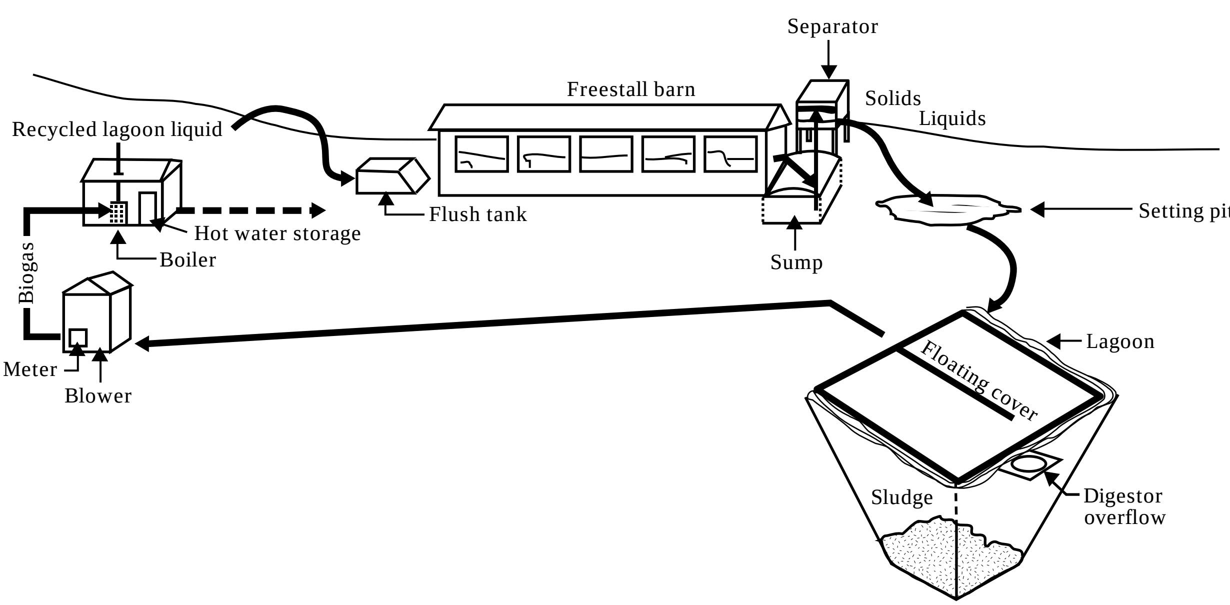
A design for a biogas production operation used for 4 years at North Carolina State University's Randleigh Dairy, in Raleigh, is shown in figure 12–108 (Williams 1994). The dairy was discontinued in June 1993. This design used an 80- by 100- by 25-foot deep anaerobic lagoon with a float supported weighted fabric cover to collect the gas and control odor. The floating cover is essential to this installation, and its design and installation by a reputable manufacturer is emphasized. The regenerative blower size and operation are critical to remove gas as it is produced and yet not collapse the airtight cover. To better predict an onsite feasibility, more data are needed on using this equipment at different locations, ambient temperatures, and production rates (Safley & Westerman 1992).

The following related equipment was included and used for the Randleigh Dairy biogas production system (Safley and Lusk 1991, Williams 1994):

- 72- x 80-foot floating fabric cover (HYPALON @DuPont) with 325 feet of Ethafoam@ float logs, 480 feet of 2-inch diameter PVC cover weight pipes, and 150 feet of 0.375-inch tiedown chain
- 80 feet of 4-inch diameter PVC perforated digester gas collection header pipe
- 650 feet of 2-inch diameter PVC gas pipe with a O.25-horsepower blower motor
- 1,500 ft^3 per hour gas meter (Dresser 1.5M175)
- 160,000 BTU boiler with 250-gallon hot water storage tank and 50 feet of 1-inch diameter hot water piping
- 2-horsepower lagoon effluent flushing pump
- 350 gallons per minute effluent pump to separator
- 4-foot diameter SWECO vibrator type solid/liquid separator
- 12- by 12- by 4-foot grit settling tank, reinforced concrete
- 0.5-horsepower effluent pump to digester
- 0.33-horsepower surface cover rainwater pump
- associated electric wiring and controls

Several, commercial-sized waste digesters for biogas were constructed in the 1970's at cattle feedyards in the South and Midwest to use feedyard wastes. In addition to the methane to be used for commercial electric generator power, utilization of the digester waste for feed or mulch was planned to help recover investment and reduce operating costs. Out of four installations, the digester in continued operation used waste from a covered confinement beef feeding barn (Eftink 1986).

Figure 12–108 Biogas equipment that has basin with fabric cover (Safley & Westerman 1992)



Gleaning from the results of these and other biogas production installations, J.M. Sweeten (1980) concluded the following keys to economical methane production from outdoor feedlot wastes:

- Collection of high quality manure from the feedlot surface.
- Efficient processing of feedstock, including ash removal.
- Low cost construction of digester.
- Efficient recovery and drying of high protein solids from digested slurry.
- Heat recovery from internal combustion engines used to convert methane into electricity.
- Large manure tonnage to achieve economics of scale.
- Efficient marketing of all by-products: methane, foodstuffs, fertilizer, and perhaps waste heat and carbon dioxide.

A 1992 survey of on-farm digester installations in the United States determined that out of 113 publicized installations, 93 had been constructed and 26 of those were operational at that time (Cantine 1992). The 93 included units at 10 different research stations. Constructed for research and demonstration purposes, most of the 93 units were closed because of the daily labor needed and the lack of continued funding for research.

Considering these experiences, detailed planning is essential about all the equipment required for a successful biogas production system from agricultural wastes. It is recommended to have the design made by an experienced, reputable consultant.

AgSTAR is a national cooperative effort of USDA, Department of Energy, and the Environmental Protection Agency to encourage the voluntary use of effective technologies to capture and utilize methane gas resulting from the anaerobic digestion of livestock waste. The effort also involves industry and agricultural partnerships to remove the barriers in use of the technology.

The goal of AgSTAR is to reduce methane emissions from livestock manure contributory to the greenhouse gases and global warming. Anthropogenic (human caused) methane emissions from coal mining, landfills, natural gas systems, domestic livestock, and livestock manure are significant. Of these emissions, it is estimated that 10 percent are from livestock manure storage and treatment facilities.

The focus of the AgSTAR program is in regions of the country where there are significant numbers of confined livestock and electric costs are high. In these regions, methane and recovery for energy generation can be economically feasible as well as a means of reducing odors. An important part of the AgSTAR program is charter farms that will be used to demonstrate methane recovery technology.

651.1208 Other associated equipment

In addition to the equipment for collection, storage, transfer, treatment, and utilization of wastes described thus far in chapter 12, varied other equipment is used with agricultural waste handling. The pertinent equipment for safety, odor evaluation, gas detection, and water quality is especially important. Equipment from alarms and backhoes to hoists to weigh scales (and more) get involved in typical operations, but they will not be included in chapter 12.

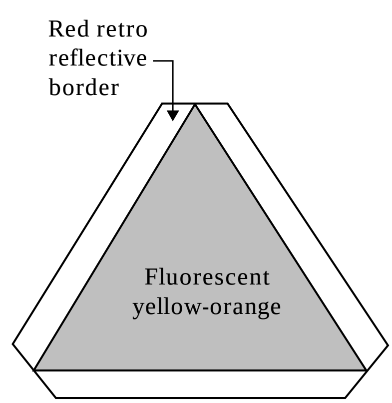
(a) Safety protection equipment

Agricultural waste handling involves hazards (651.1008). Waste handling equipment is often operated alone at all hours of the day and in a dirty, noisy, slippery, remote, semi-dark location, which is generally a long way from help and medical attention. Safety considerations made when planning facilities are essential and have been briefly included in this chapter. They are covered in depth in chapter 13. Workers should be knowledgeable about hazards, safe operation conditions, emergency procedures, phone numbers, and available medical facilities.

(1) Signs for safety, danger, and warning situations

Waste handling involves the use of slow moving equipment. The Slow Moving Vehicle (SMV) warning emblem (fig. 12–109) is mounted on the rear of equipment traveling less than 25 miles per hour on public roads. The emblem is mounted 2 to 6 feet above the ground, centered or to the left (whichever is most practical), and pointing upward. ASAE Standard S276.3 explains the specifications about SMV sign construction and use (ASAE [r] 1994). As with any equipment, the sign needs to be in good repair and regularly cleaned.

Figure 12–109 Slow moving vehicle emblem



Somewhat comparable to the SMV emblem is the Safety Alert Symbol for Agricultural Equipment (fig. 12–110). As explained by the ASAE Standard S350, the uniform symbol is to be used with warning statements, signs, manuals, and educational materials about agricultural equipment (ASAE [s] 1992). It is not to be used alone.

ASAE Standard S441, Safety Signs, is useful for signs needed with agricultural waste handling situations (fig. 12–111). This standard provides design guidelines for uniform safety signs, their situations, format, colors, size, and placement (ASAE [p] 1995). Uniformity in signs assists quick recognition and understanding. Work situation signal words include:

Danger High probability of death or irreparable injury.

Warning Hazard exists that could result in injury or death.

Caution Precaution needed against personal injury.

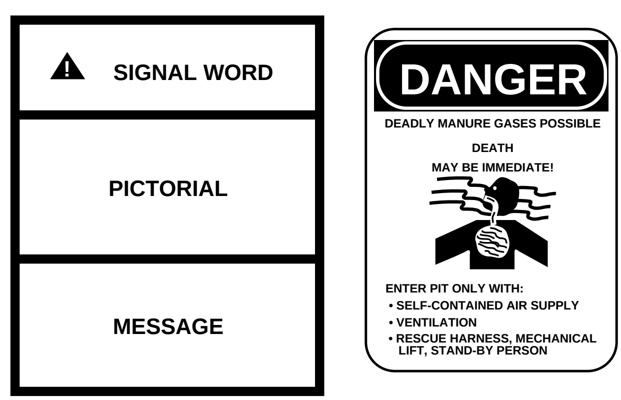
Warning sign situations would be where waste scraping, storage, agitation, or loading take place. ASAE Standard S441 explains that the warning sign needs a black background behind the signal word, which is to be in yellow letters. The message is black lettering on a yellow background. It is printed in 2-inch-high letters so it can be seen from about 80 feet away.

A **Danger** sign to be used near earthen basin waste storages was developed in Pennsylvania (Bowers 1992). This 10- by 14-inch aluminum sign generally follows the ASAE Standard 441 guidelines (see fig. 12–111). It is available through the D.W. Miller Industries, Inc., RD #1, Box 7B, Huntington, PA 16652.

Other pertinent ASAE standards for safe use of waste handling equipment include S344.3, Safety for Farmstead Equipment; S318.10, Safety for Agricultural Equipment; and S355.1, Safety for Agricultural Loaders. These respectively explain guarding, operation, safety needs, and references for their development (ASAE 1995).

Figure 12–110 Safety alert symbol for agricultural equipment

Figure 12–111 Safety signs format



(2) Fire extinguishers

Local fire departments, insurance agencies, and fire extinguisher sales and service shops are knowledgeable about fire extinguishers. Only a brief explanation is given here.

A full and operable 2A-10BC fire extinguisher (or larger) should be nearby where engines are operated. It will smother trash, paper, petroleum, and electrical fires (Fanning 1984).

Fires and extinguishers are classified as A, B, C, or D according to the material that is burning. Because of the characteristics of the different fires, the extinguisher that works on one type fire may be dangerous or ineffective on another. The classifications are:

- Class A — Combustible solids, such as wood, straw, or rubbish.
- Class B — Flammable liquids, such as gasoline, paint, or oil.
- Class C — Energized electric equipment, such as motors or switches.
- Class D — Combustible metals, such as magnesium and sodium.

Fire extinguishers need to be tested by an approved agency. The fire extinguishing potential for the fire classification is rated and put on the label. The rating is a number and letter combination. The letter indicates the fire type and the number indicates the size of fire the extinguisher will put out (fig. 12–112).

The ratings for Class A fire extinguishers show the relative extinguishing potential of one model compared to another. A 4A extinguisher should extinguish twice as much Class A fire as a 2A. The number on Class B fire extinguishers indicates relative size and the square foot area of deep layer flammable liquid that an average operator can extinguish. For example, a 6B unit should extinguish 6 square feet of deep layer flammable fire. A 6B unit will also extinguish twice as much Class B fire as a 3B.

Class C fires are either Class A or Class B fires with electrical equipment present. The C rating is the same as the Class A or the Class B rating depending on what is burning.

Dry chemical extinguishers are available from 2.5 to 20 pound sizes. The dry powder that smothers the fire is propelled by pressurized nitrogen or carbon dioxide gas. A dry chemical extinguisher is effective on Class B and C fires. It will knock down a Class A fire, which may then need water to completely smother smoldering materials. The remaining dry chemical residue is a disadvantage of using this type extinguisher on a Class A fire.

Figure 12–112 Fire extinguisher label

UL UNDERWRITERS LABORATORIES INC. ®
LISTED
DRY CHEMICAL FIRE EXTINGUISHER
CLASSIFICATION 2-A: 10-B:C

(b) Gases and confined space entry

Air quality in agricultural waste handling systems is explained in section 651.0305. Information about safety considerations are included in sections 651.1008 and 651.1204 and in chapter 13. Attention continues to focus on the air quality and safety aspects of handling agricultural wastes (Berg 1994). Protection and first aid is a concern for workers and for inspectors, visitors, and especially children.

Depending on employee numbers, family workers, corporate status, and perhaps State rules, the United States Department of Labor, Occupational Safety and Health Administration (OSHA) can become involved with agricultural production operations (U.S. HHS 1990). The OSHA promulgated a standard (Congressional Federal Register 1910.146) dealing with entry into confined spaces in April 1993 (Shutske et al. 1993). This action may have implications to confined spaces in agricultural related facilities. Included, for example, might be worker training, warning signs, and safety equipment and its approval and use.

In working with agricultural wastes, an operator at some time will need to enter and work in an enclosed storage or tanker space where there may be dangerous gases or absence of oxygen (Berg 1994). The confined space must be completely force-ventilated with a blower and flexible duct. If at all possible, employ an experienced person with proper equipment to do the work. Contacts about who can do this should be available through waste equipment suppliers, safety specialists, local emergency rescue concerns, fire departments, law enforcement persons, electric and gas power suppliers, military stations, underwater equipment suppliers, and related agencies. Suppliers and licensed operators should have current rescue procedure information and operable equipment.

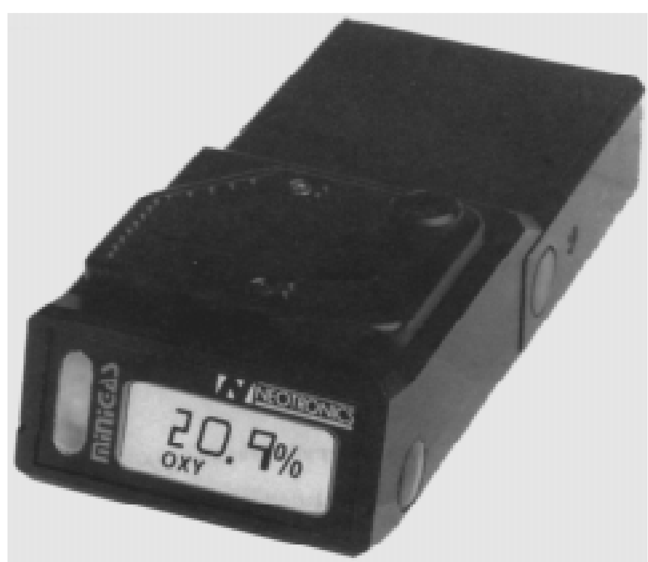
The minimum equipment used by a trained person when entering a confined space would be (Shutske et al. 1993):

- A monitor to test and provide continuous detection capabilities for presence of hydrogen sulfide (H_2S), methane (CH_4), and oxygen (O_2) before and during entry.
- A ventilation blower (1,000 cubic feet per minute) with about 15 feet of flexible ducting that can reach spaces requiring venting.
- A lifeline and harness system (tripod, cable, winch) to allow a helper to quickly remove an entrant in the event of a storage incident.

The same types of equipment are required by the confined space entry guidelines for manure pits (storages) issued in 1990 by the National Institute for Occupational Safety and Health (U.S. HHS 1990).

A portable, electronic gas monitor capable of detecting O_2 levels below 19.5 percent, H_2S levels above 15 ppm, CH_4 levels above 10 percent of the lower, explosive limit, and other combustible gases is advised. Most detectors have a calibration kit for that detector. An electronic detector measures the electrical variations of an exposed, special coating on a sensor. The sensor life would be dependent on use, gas concentration, and other environmental factors (fig. 12–113). Many different models are available. A single instrument could use several independent sensors to measure different, respective gases (e.g., H_2S, CO, O_2). In addition to a digital display of gas level, such detectors are available with alarm lights, audio alarm, and detachable sensors for remote monitoring.

Figure 12–113 Hand-held electronic multigas detector (courtesy Neotronics)



A hand-held air sampler with different indicator tubes (fig. 12–114) is moderate cost and remains reliable after repeated use. However, this detector is slower to operate than the electronic detector. The sealed sampler tubes are available for sensing different gases. To do a sample, a selected tube is broken open and inserted in the sampler. The plunger is extended to draw a specific quantity of air through the sample tube material, and the change of tube color is compared to a standard chart.

A wetted-paper gas level indicator costs less than any other indicator, but the indication response may be slower. Contamination of this indicator is possible, which then would not give a reliable indication. This indicator can be more cumbersome to use in typical situations involving agricultural wastes.

While self-contained breathing equipment (fig. 12–115) use is often suggested, many people are relatively unfamiliar with how to use it. The concerns with this equipment include high investment cost, need for knowledgeable operation, and correct maintenance, servicing, and replacement parts.

Self Contained Breathing Apparatus (SCBA) equipment is available in different configurations—closed or open circuit, pressure demand, or demand. A closed circuit apparatus removes CO_2 from exhaled breath and then restores O_2 content from a compressed O_2 or O_2 generating source. It generally has a longer service life than that of the open circuit apparatus. Open circuit equipment allows exhaled air to escape to the atmosphere and supplies breathing air from a compressed air source.

Pressure demand equipment maintains a slight positive pressure in the face piece, which eliminates inward leaking of atmospheric contaminants. This equipment is suitable for Immediately Dangerous to Life and Health (IDLH) environments, whereas the demand device is not suitable. Both types are suitable for O_2 deficient environments depending on the service life of the air source. Different kinds of face masks and user head protection can be used with the SCBA.

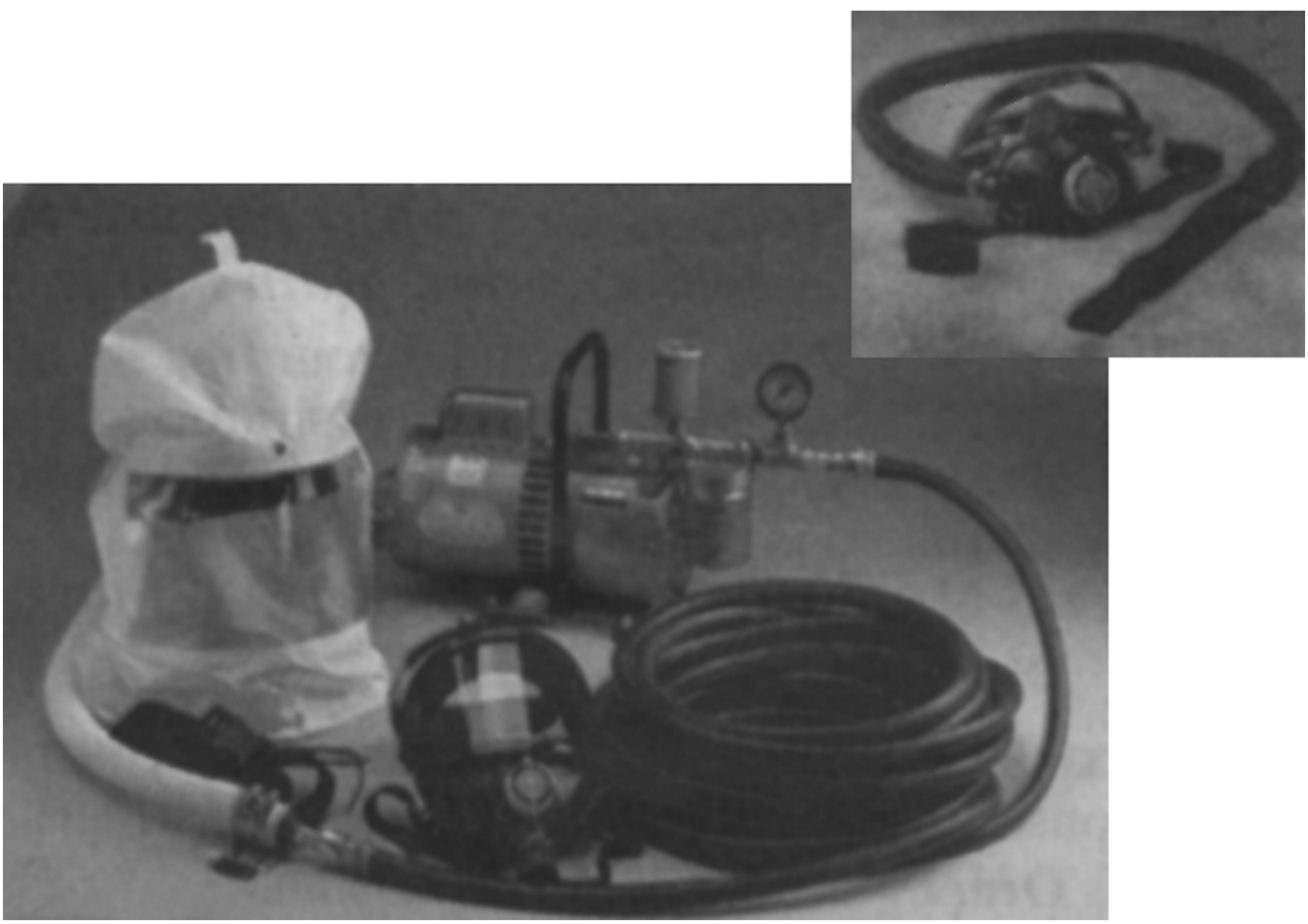
Figure 12–114 Air sampler with different gas detection tubes (courtesy Sensidyne, Inc.)

Figure 12–115 Self contained breathing equipment (courtesy Willson Safety)

The OSHA requires workspace respirator equipment to be tested and certified by the National Institute for Occupational Safety and Health (NIOSH). Respirator equipment is either the filtering and conditioning type that uses workspace air without adding anything to it or the air-supplied type that includes the Self Contained Breathing Apparatus (SCBA). The NIOSH approval is an assurance of quality. However, this approval is for new equipment, so wear, time, or abuse can negate this credibility. If the operator is not sure how to operate this equipment and the user manual is not available, the manufacturer of the equipment or the NIOSH should be consulted for items to check before use.

Relatively low cost outside atmosphere Supplied Air Respirator (SAR) equipment is generally available (fig. 12–116). An air-compressor, supply hose, and lightweight hood or face mask make up this equipment. SAR equipment is designed for use in dusty, humid, smelly, warm, or other such contaminated environments where an adequate supply of oxygen is present. It is not recommended for use in an atmosphere IDLH environment. Selection depends on the compressor capacity (rated in ft^3/m), filter quality, and hood supply hose type and length. Equipment is available that has a 5- to 10-minute emergency or exit air bottle attached. This air supply is the critical backup should something happen to the air supply hose.

Figure 12–116 Supplied air respirator equipment (courtesy Gempler's)



A tripod is used as the overhead anchorage for a winch hoist. The hoist is attached to a leather or web harness and used to raise and lower a person through a small opening, such as a manhole. A waist belt and shoulder straps have an attached ring at the back. Rescue harness and winch hoist equipment should be able to lift at least 500 pounds as it may need to support two persons (fig. 12–117). The winch needs a sturdy, smooth-operating, unwind latch to prevent unwanted release or jamming. The support frame needs workspace clearance for the harness and the person in it.

A rope located by a ramp or storage facility can provide a practical means of emergency escape. A nondegrading material, such as nylon, that is at least 0.75 inches in diameter is suggested. The rope should be knotted at 1-foot intervals (Bowers 1992). The rope can be used by anyone who accidentally falls into a storage to hold onto until help arrives or possibly to climb out.

Figure 12–117 Tripod, winch, and harness (courtesy D B Industries, Inc.)

(c) Odor detection/measurement equipment

Waste storage facilities and handling equipment produce offensive odors. Odor complaints about field spreading are increasing. Odor detection is relatively easy, but measurement is more difficult. Even though the human nose is an effective detector, it lacks constant sensitivity and varies among people.

Odorous gases are a combination of end and intermediate products of anaerobic decomposition that have enough volatility to escape from the liquid phase. More than 100 odor causing compounds are in agricultural wastes operations. Although research has been done on odors from waste, practical measurement of specific compounds at relatively low concentrations (<1 ppm) remains a problem (Bundy 1993, McFarland and Sweeten 1993). Gas-liquid chromatography equipment has been primarily used in odor identification. With highly sensitive detector equipment, frequently other compounds present in great concentration, but less odor significance, tend to interfere with analysis (MWPS 1983).

Reliable detector equipment is useful with odor reduction efforts where the general effectiveness of odor control treatment must be determined. An electronic indicator (fig. 12–118), for example, is useful to detect odor presence. Presently, this equipment is unable to detect specific odors; however, it can help quantify odors by using the relative response of the readout. Calibration to a specific compound is possible by exposing the meter to a known concentration and developing a graph.

Two aspects of odor are intensity and quality. The intensity of an odor is defined as the number of dilutions required to reduce the odor to the threshold level, which is the least distinguishable concentration of that odor. A scentometer (fig. 12–119) is useful for field measurement of odor intensity.

The scentometer is a 5- by 6- by 2.5-inch box with two ports through which air passes through activated charcoal beds. The four odorous air inlets are directly connected to a mixing chamber, which is connected to the nasal outlets. In use, several scentometers are taken to where an odor intensity measurement is desired. Each scentometer is used by a different observer. The observers place the nasal outlets to their nose and plug the odorous air ports to adjust their sense of smell to odor-free air. The person then opens successive ports until an odor is detected through the scentometer. Although subject to considerable variation, the results are useful to rank odor intensity (MWPS 1983). For relative comparison of more average conditions, odor measurement locations should be about 20 feet from lagoons and 50 feet from barns (Bundy 1993).

The butanol olfactometer (fig. 12–120) allows panelists to compare the intensity of odor in ambient air (without dilution) to the intensity of a dilute concentration of 1-butanol gas (C_4H_9OH). This approach is more useful with higher odor intensities. It is known as supra-threshold referencing, which is desirable to eliminate the odor threshold variability among panel observers. While portable, this equipment is heavy, relatively delicate and cumbersome, and requires expertise and time to operate. The data are generally more reliable than that of other odor measurement devices (Sweeten et al. 1984).

Figure 12–118 Odor measurement electronically (courtesy Sensidyne, Inc.)

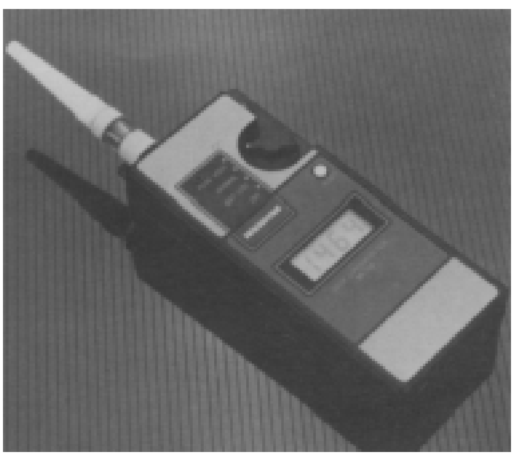


Figure 12–119 Scentometer for odor strength measurement (MWPS 1983)

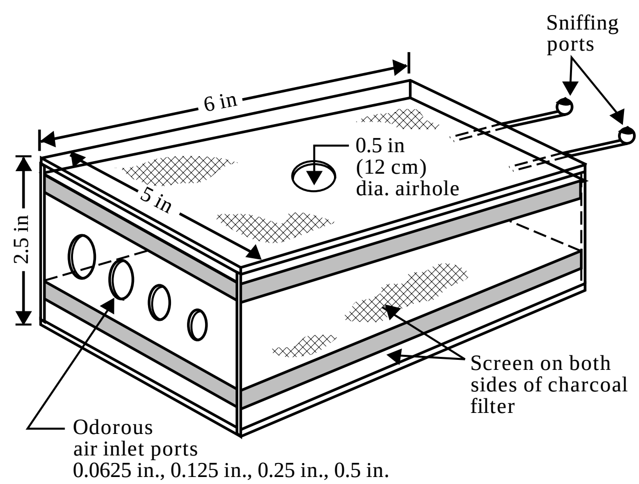
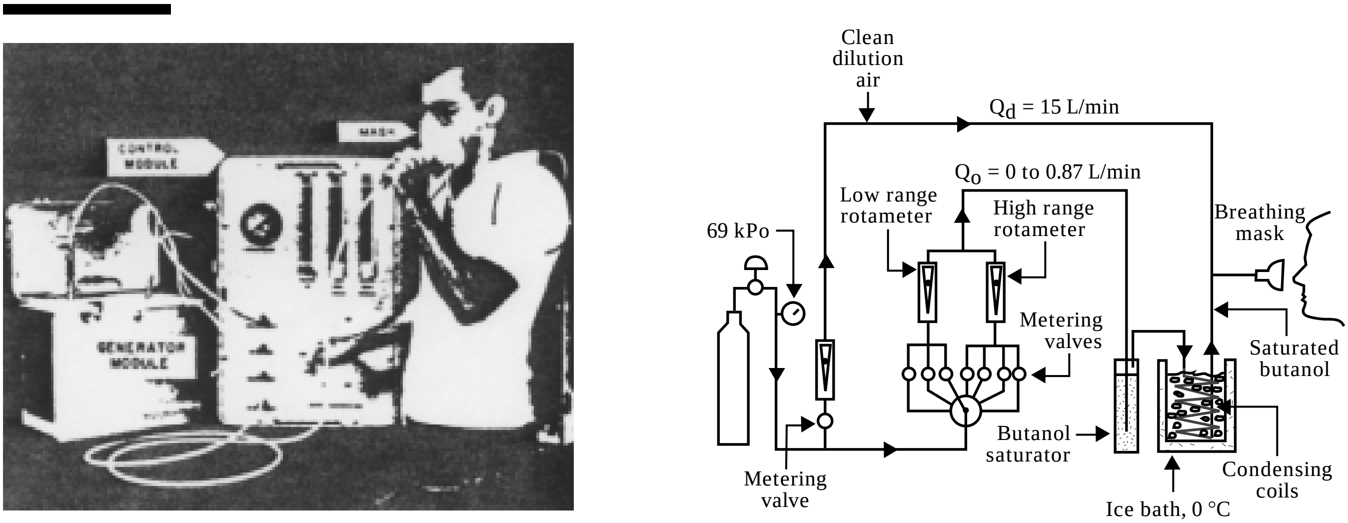


Figure 12–120 Butanol olfactometer for odor measurement (Sweeten et al. 1984)



Europeans have equipment for collecting an odor sample in a plastic or teflon bag. The sample is tested in a laboratory using an olfactometer (Bundy 1993).

In contrast to determining odor strength, odor quality is more difficult to define. One technique is comparing an odor to a familiar sensation categorized as foul, sweetish, acetate, nut-like, putrid, butter-like, and garlic. A less-specific alternative is to rank the offensiveness from 1 to 10 (Dickey 1978).

Physical means to manage odors include the use of covers, aeration, and such waste management practices as locating the waste treatment facilities away from people, cleaning and keeping the facilities dry, and using wind barriers. Management for odor reduction, odor sources, and the different odor reducing chemicals are reviewed in the ASAE Engineering Practice 379.1 (ASAE [k] 1991).

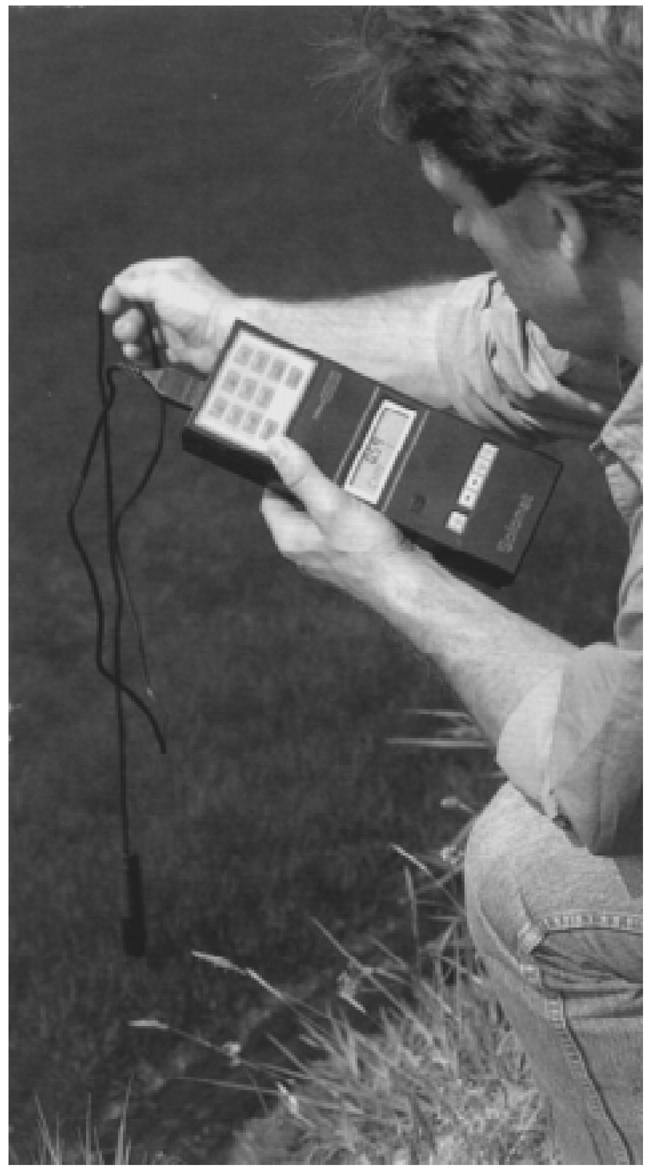
(d) Water quality testing equipment

The equipment described in the previous section is all an integral part of a waste management system planned and installed to protect water quality. Knowledge of equipment used to measure water quality is useful; however, the actual sampling and analysis normally require a skilled specialist.

State agencies are responsible for monitoring public water quality. Most public drinking water supplies are regularly checked for their quality. While there are Federal minimum quality standards, individual State standards may be stricter. Water quality is generally assessed by respective equipment or laboratory processes that measure coliform bacteria, pH, turbidity, hardness, dissolved solids, nitrates, phosphorus, and odor.

Except for the bacteria test, which requires a culture and microscope, quality tests on these items can be done manually using a color-comparison, visually judged result; with portable electronic equipment out in the field (fig. 12–121); or more reliably using electronic and oven equipment in controlled laboratory conditions. For analysis, selecting and getting an accurate water sample in an approved container is critical. Then correct handling and transporting the sample to the laboratory is another challenge.

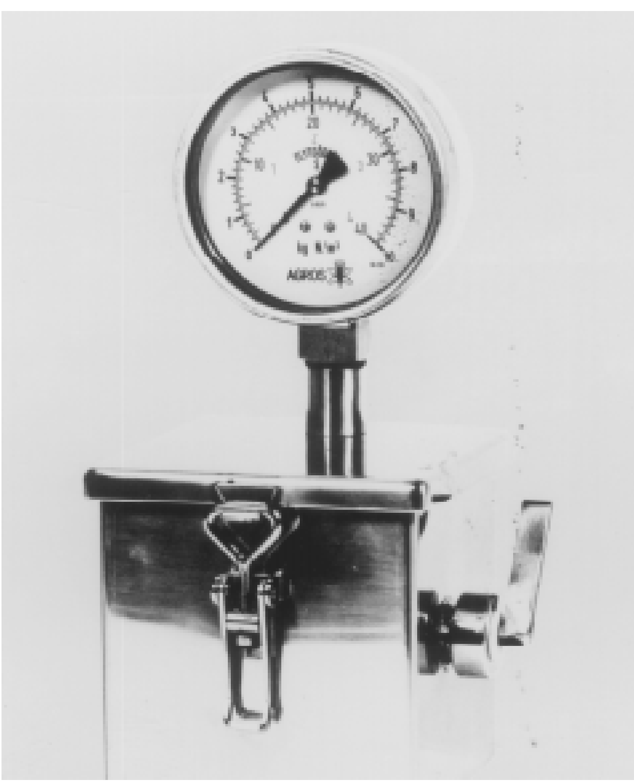
Figure 12–121 Water quality measurement electronically (courtesy Solomat Neotronics)



In addition to these more common water quality measurement items, chemical analysis in the laboratory can be made for arsenic, barium, boron, cadmium, chlorine, chromium, copper, fluorine, iron, lead, maganese, selenium, sulfate, zinc, and individual pesticides.

Although what develops from application of agricultural waste to soil is not directly related to water quality testing, it is closely related. Knowledge about how much waste to apply relates to the soil quality and the waste quality. Sections 651.0605, 651.0904(f), 651.1006, 651.1102, and 651.1207 give more details of application of wastes to soil. Also see NRCS Conservation Practice Standard, Nutrient Management, Code 590. Figure 12–122 shows a direct reading nitrogen meter that can assist with soil nitrogen management.

Figure 12–122 Direct-reading portable nitrogen meter (courtesy Agri-Waste Technology, Inc.)



651.1209 References

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